Protective Device Coordination

ETAP Star

Agenda

- Concepts & Applications
- Star Overview
- Features & Capabilities
- Protective Device Type
- TCC Curves
- STAR Short-circuit
- PD Sequence of Operation
- Normalized TCC curves
- Device Libraries

Definition

- Overcurrent Coordination
  - A systematic study of current responsive devices in an electrical power system.

Objective

- To determine the ratings and settings of fuses, breakers, relay, etc.

- To isolate the fault or overloads.

Criteria

- Economics
- Available Measures of Fault
- Operating Practices
- Previous Experience

Design

- Open only PD nearest (upstream) of the fault or overload
- Provide satisfactory protection for overloads
- Interrupt SC as rapidly (instantaneously) as possible
- Comply with all applicable standards and codes
- Plot the Time Current Characteristics of different PDs

Analysis

When:

- New electrical systems
- Plant electrical system expansion/retrofits
- Coordination failure in an existing plant

Spectrum Of Currents

- Load Current
  - – Up to 100% of full-load
  - – 115-125% (mild overload)
- Overcurrent
  - – Abnormal loading condition (Locked-Rotor)
- Fault Current
  - – Fault condition
  - – Ten times the full-load current and higher

Protection

- Prevent injury to personnel
- Minimize damage to components
  - Quickly isolate the affected portion of the system
  - Minimize the magnitude of available short-circuit

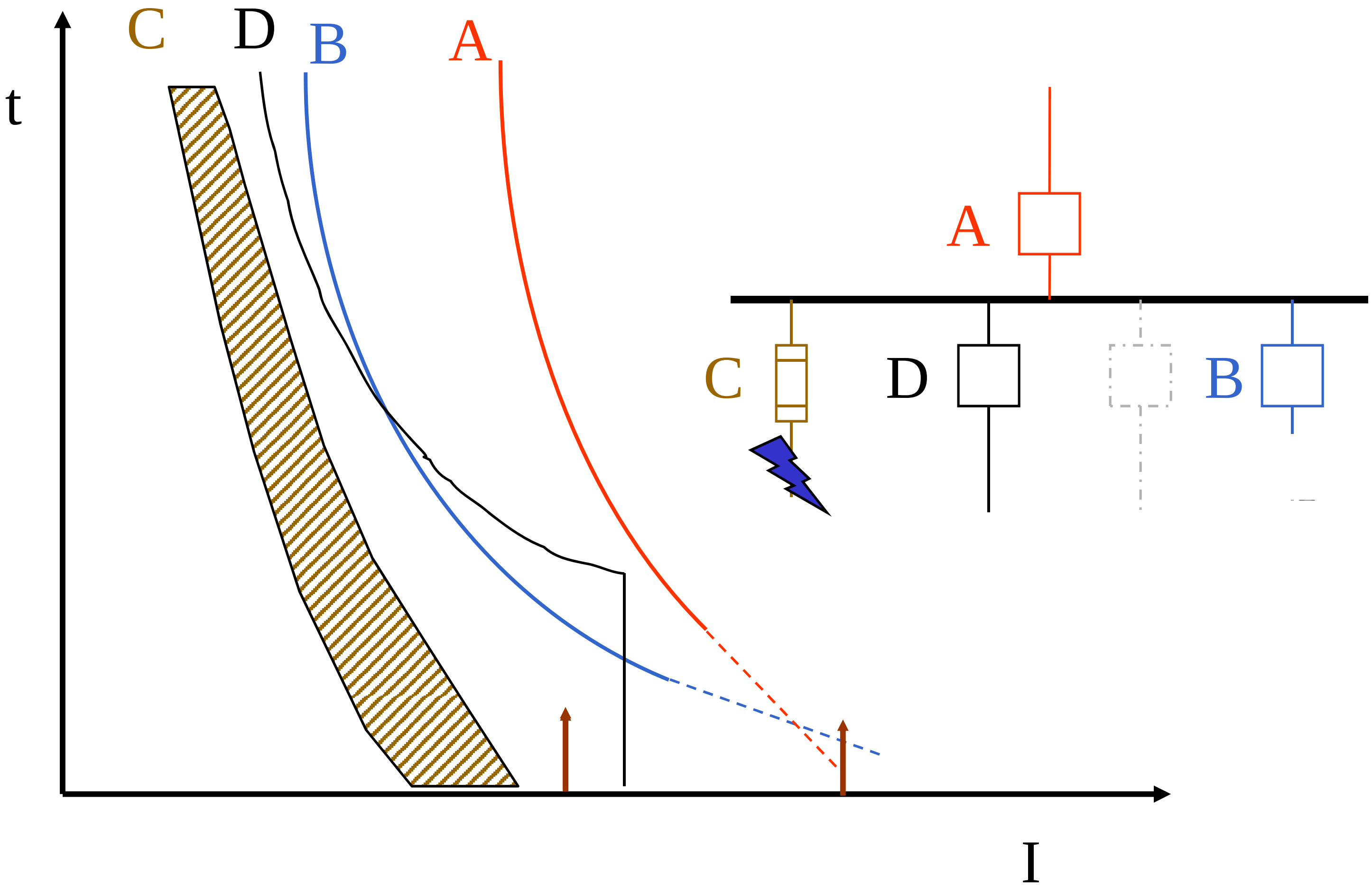
Coordination

- Limit the extent and duration of service interruption

- Selective fault isolation

- Provide alternate circuits

Coordination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D
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B

Protection vs. Coordination

- Coordination is not an exact science
- Compromise between protection and coordination
  - Reliability
  - Speed
  - Performance
  - Economics
  - Simplicity

Required Data

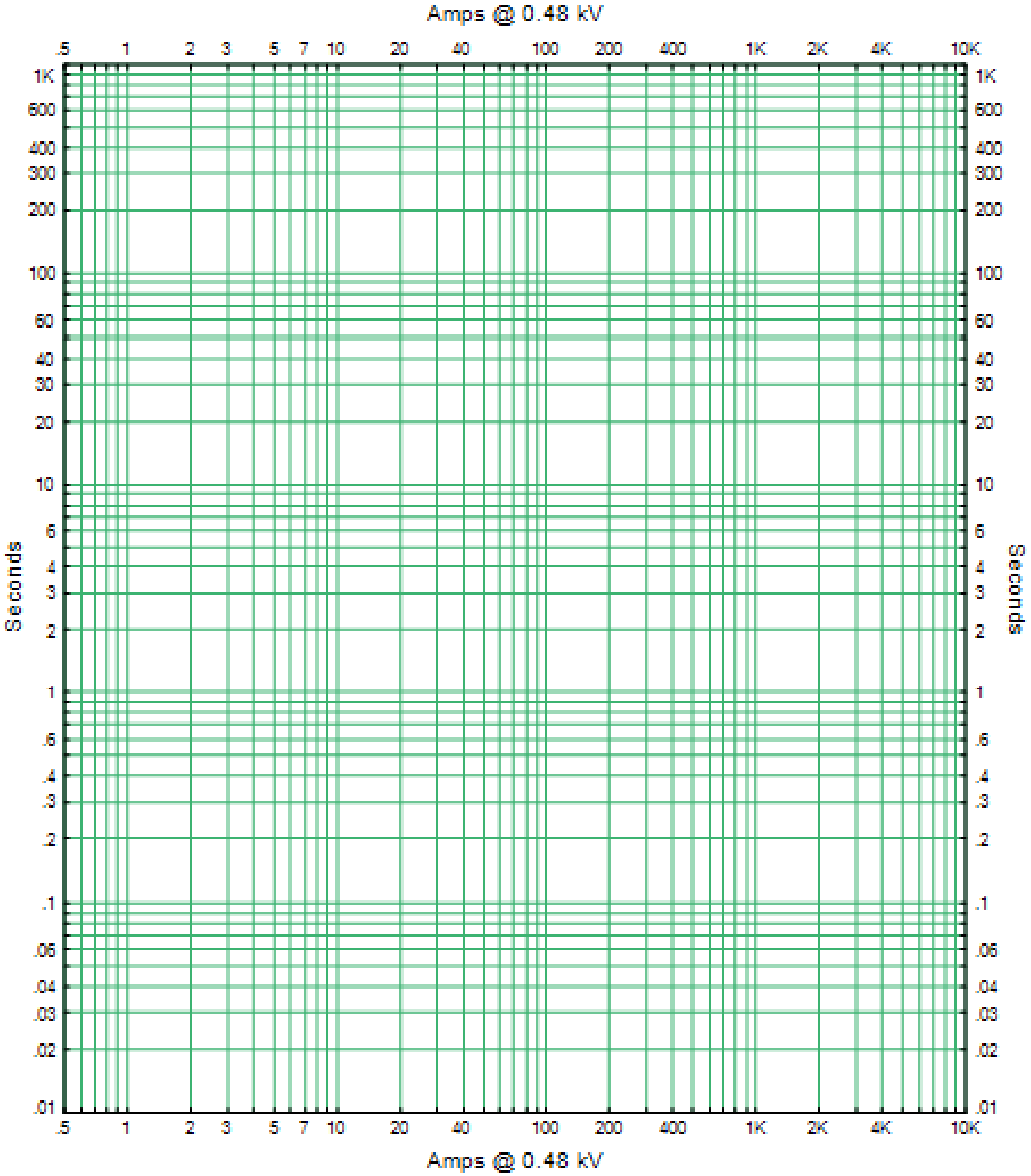
- One-line diagrams (Relay diagrams)
- Power Grid Settings
- Generator Data
- Transformer Data
  - Transformer kVA, impedance, and connection Motor Data
- Load Data
- Fault Currents
- Cable / Conductor Data
- Bus / Switchgear Data
- Instrument Transformer Data (CT, PT)
- Protective Device (PD) Data
  - Manufacturer and type of protective devices (PDs)
  - One-line diagrams (Relay diagrams)

Study Procedure

- Prepare an accurate one-line diagram (relay diagrams)
- Obtain the available system current spectrum (operating load, overloads, fault kA)
- Determine the equipment protection guidelines
- Select the appropriate devices / settings
- Plot the fixed points (damage curves, …)
- Obtain / plot the device characteristics curves
- Analyze the results

Time Current Characteristics

- TCC Curve / Plot / Graphs
- 4.5 x 5-cycle log-log graph
- X-axis: Current (0.5 – 10,000 amperes)
- Y-axis: Time (.01 – 1000 seconds)
- Current Scaling (…x1, x10, x100, x100…)
- Voltage Scaling (plot kV reference)
- Use ETAP Star Auto-Scale

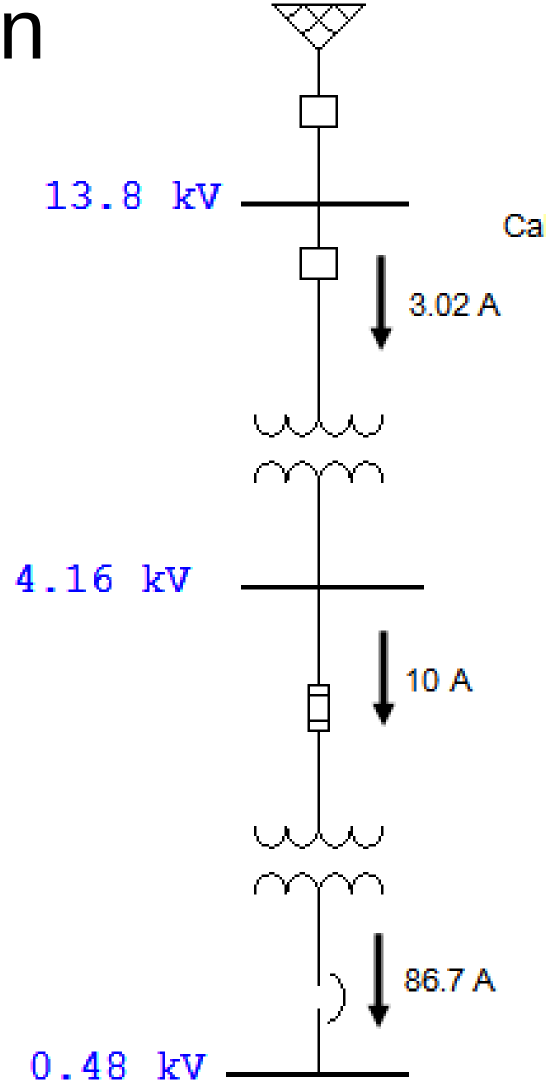

Amps @ 0.48 kV
.5
1
2
3
5
7
10
20
40
100
200
400
1K
2K
4K
10K
Seconds
1K
600
400
300
200
100
60
40
30
20
10
6
4
3
2
1
.6
.4
.3
.2
.1
.06
.04
.03
.02
.01

TCC Scaling Example

- Situation:
  - A scaling factor of 10 @ 4.16 kV is selected for TCC curve plots.
- Question
  - What are the scaling factors to plot the 0.48 kV and 13.8 kV TCC curves?

TCC Scaling Example

- Solution


13.8 kV
3.02 A
4.16 kV
10 A
86.7 A
0.48 kV

Calculated Scale:
= 10 (kVs / kVp)
= 10 (4.16/13.8)
= 3.015 Amps @ 13.8 kV

Selected Scale: 10 Amps @ 4.16 kV

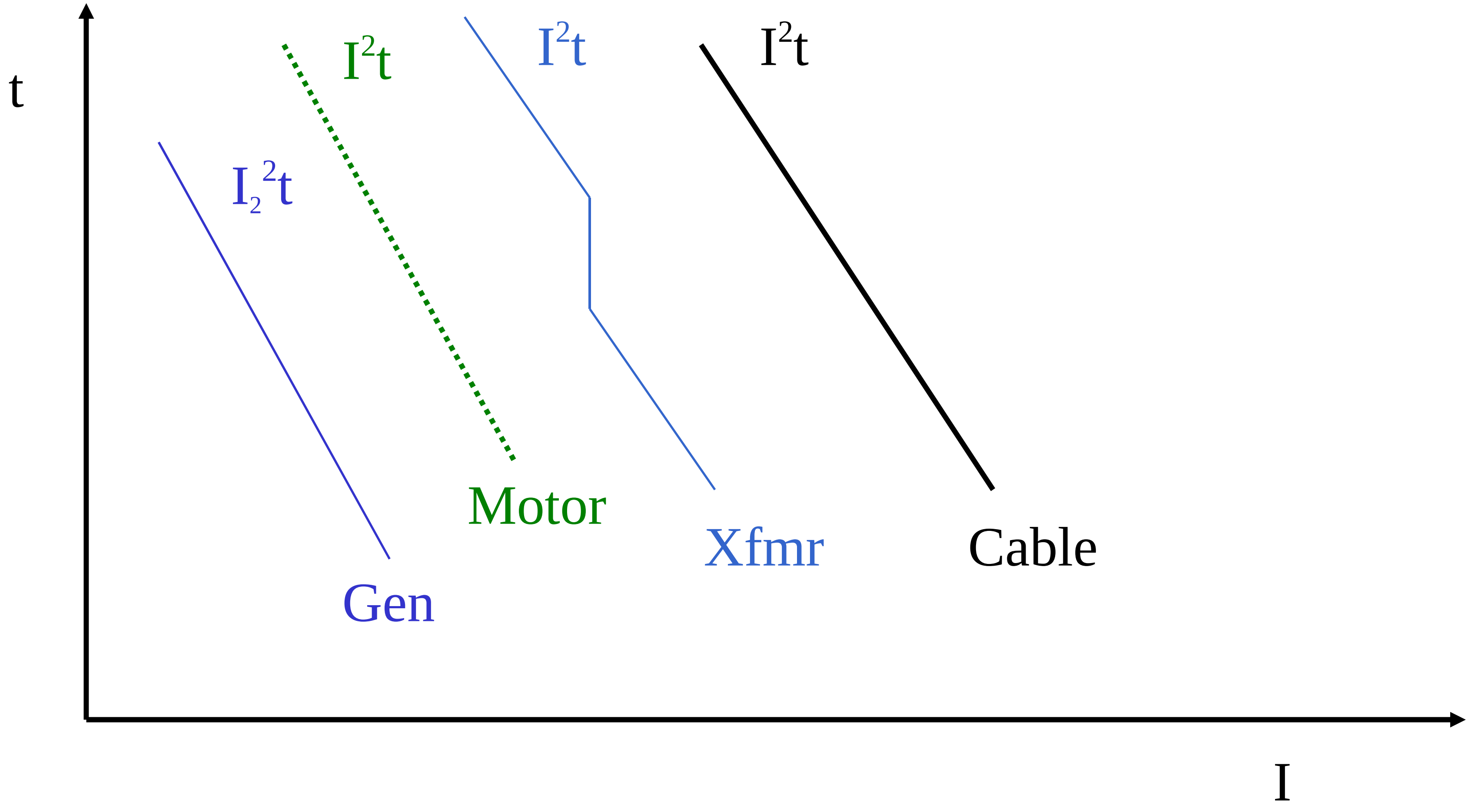
Calculated Scale:
= 10 (kVp / kVs)
= 10 (4.16/.48)
= 86.7 Amps @ .48 kV

Fixed Points

Points or curves which do not change regardless of protective device settings:

- Cable damage curves
- Cable ampacities
- Transformer damage curves & inrush points
- Motor starting curves
- Generator damage curve / Decrement curve
- SC maximum fault points

Capability / Damage Curves



Cable Protection

- Standards & References
  - IEEE Std 835-1994 IEEE Standard Power Cable Ampacity Tables
  - IEEE Std 848-1996 IEEE Standard Procedure for the Determination of the Ampacity Derating of Fire-Protected Cables
  - IEEE Std 738-1993 IEEE Standard for Calculating the Current- Temperature Relationship of Bare Overhead Conductors
  - The Okonite Company Engineering Data for Copper and Aluminum Conductor Electrical Cables, Bulletin EHB-98

Cable Protection

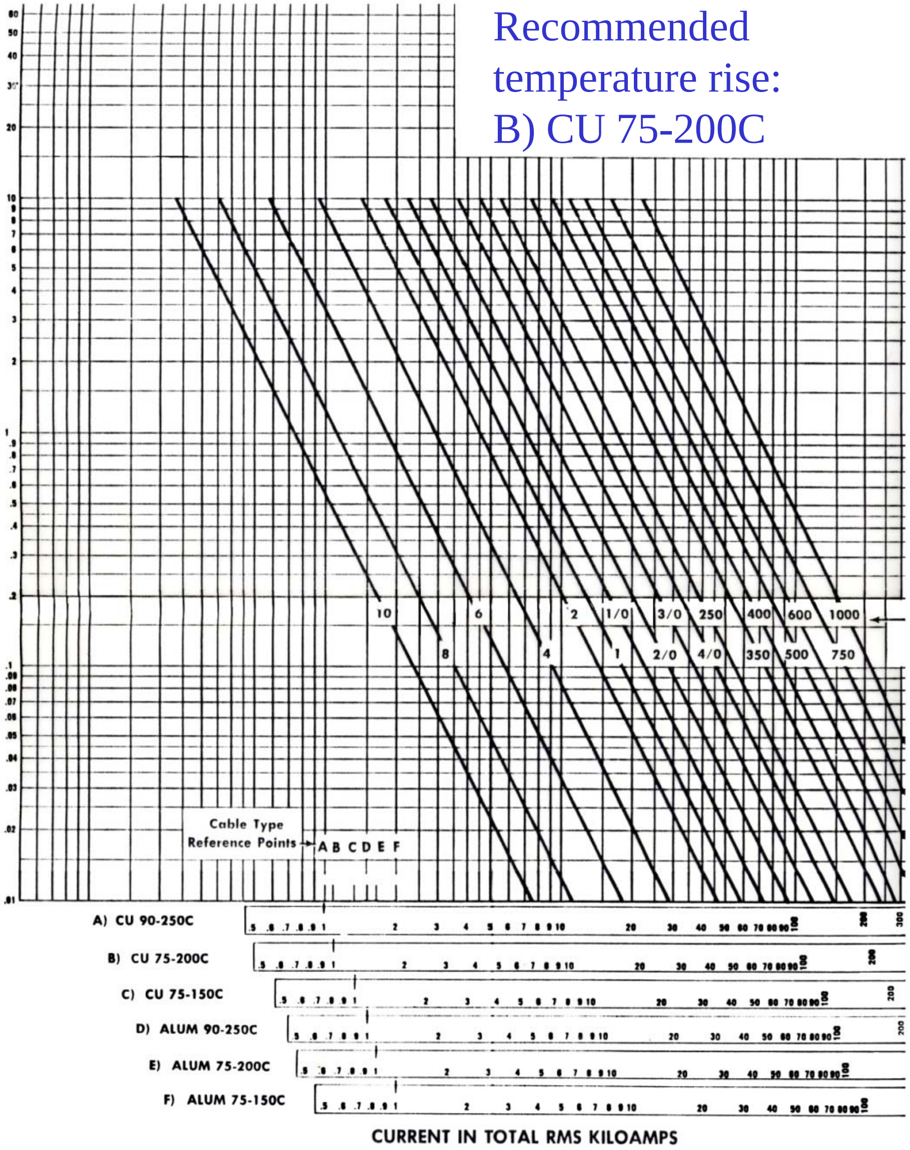
The actual temperature rise of a cable when exposed to a short circuit current for a known time is calculated by:

$$A = \sqrt{\frac{I^2 t}{0.0297 \log\left[\frac{T_2 + 234}{T_1 + 234}\right]}}$$

Where:
A= Conductor area in circular-mils
I = Short circuit current in amps
t = Time of short circuit in seconds
T_1= Initial operation temperature (75^0C)
T_2=Maximum short circuit temperature (150^0C)

Cable Short-Circuit Heating Limits

Recommended
temperature rise:
B) CU 75-200C



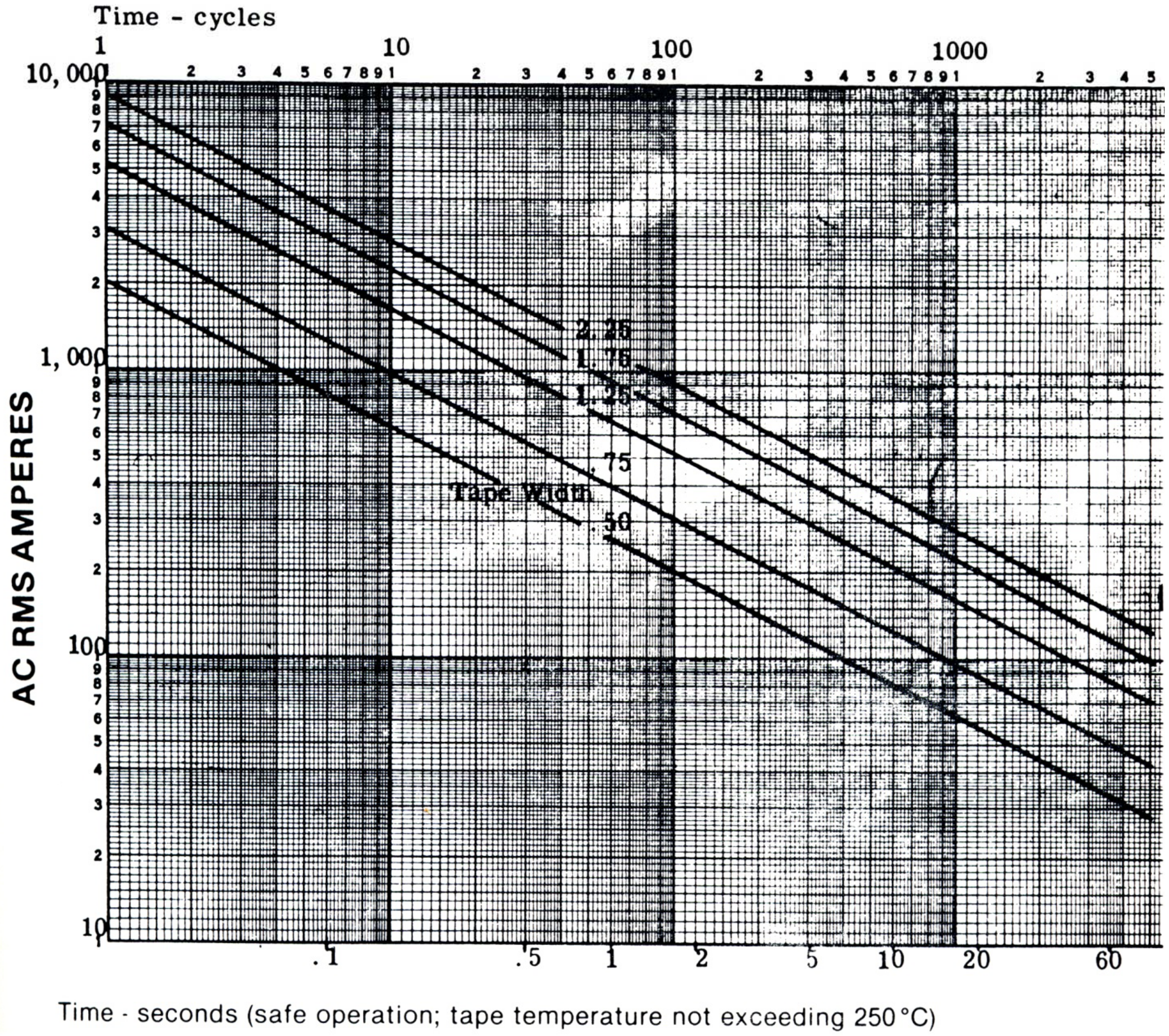
INSULATED CABLE

SHORT CIRCUIT HEATING LIMITS

Shielded Cable

The normal tape width is 1½ inches

TIME vs. FAULT CURRENT FOR SAFE OPERATION
.005 inches Tinned Copper Tape



NEC Section 110-14 C

- **(c) Temperature limitations.** The temperature rating associated with the ampacity of a conductor shall be so selected and coordinated as to not exceed the lowest temperature rating of any connected termination, conductor, or device. Conductors with temperature ratings higher than specified for terminations shall be permitted to be used for ampacity adjustment, correction, or both.
- (1) Termination provisions of equipment for circuits rated 100 amperes or less, or marked for Nos. 14 through 1 conductors, shall be used only for conductors rated 600C (1400F).
- Exception No. 1: Conductors with higher temperature ratings shall be permitted to be used, provided the ampacity of such conductors is determined based on the 6O0C (1400F) ampacity of the conductor size used.
- Exception No. 2: Equipment termination provisions shall be permitted to be used with higher rated conductors at the ampacity of the higher rated conductors, provided the equipment is listed and identified for use with the higher rated conductors.
- (2) Termination provisions of equipment for circuits rated over 100 amperes, or marked for conductors larger than No. 1, shall be used only with conductors rated 750C (1670F).

Transformer Protection

- **Standards & References**
  - National Electric Code 2002 Edition
  - C37.91-2000; IEEE Guide for Protective Relay Applications to Power Transformers
  - C57.12.59; IEEE Guide for Dry-Type Transformer Through-Fault Current Duration.
  - C57.109-1985; IEEE Guide for Liquid-Immersed Transformer Through-Fault-Current Duration
  - APPLIED PROCTIVE RELAYING; J.L. Blackburn; Westinghouse Electric Corp; 1976
  - PROTECTIVE RELAYING, PRINCIPLES AND APPLICATIONS; J.L. Blackburn; Marcel Dekker, Inc; 1987
  - IEEE Std 242-1986; IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems
  -

Transformer Category

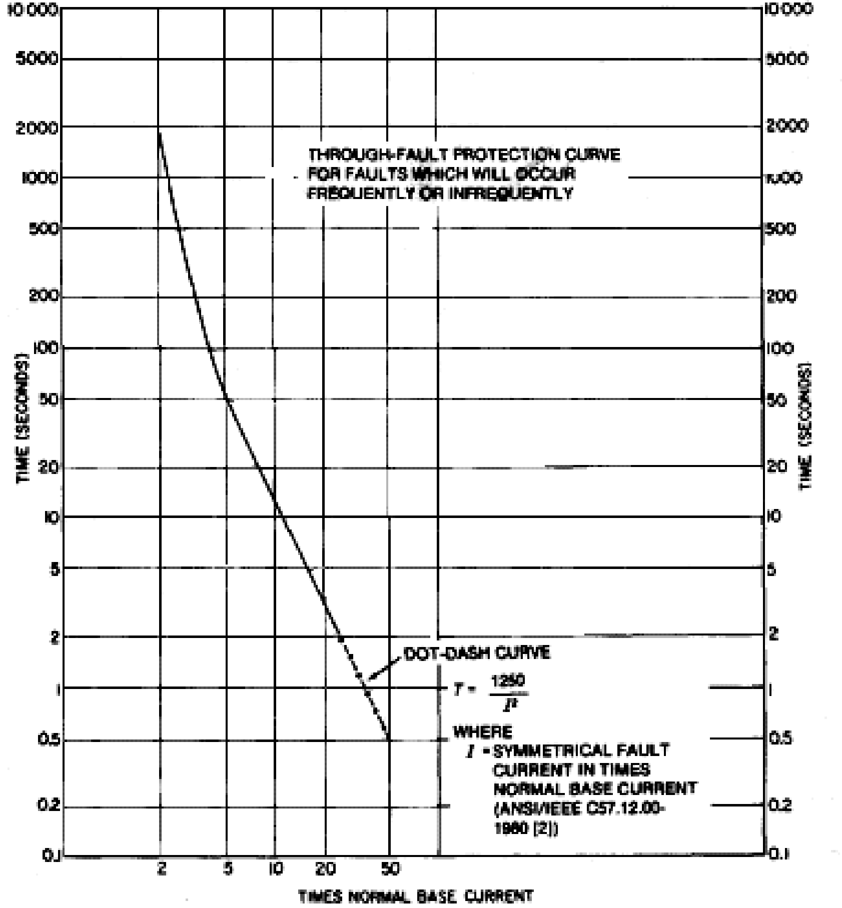
ANSI/IEEE C-57.109

	Minimum nameplate (kVA)	
Category	Single-phase	Three-phase
I	5-500	15-500
II	501-1667	501-5000
III	1668-10,000	5001-30,000
IV	above 1000	above 30,000

Transformer Categories I, II

Fig 1
Category I Transformers

NOTE: The maximum short-circuit withstand capability of Category I Transformers is defined in ANSI/IEEE C57.12.00-1980 [2]



THROUGH-FAULT PROTECTION CURVE FOR FAULTS WHICH WILL OCCUR FREQUENTLY OR INFREQUENTLY

DOT-DASH CURVE

$T = \frac{1250}{I^2}$

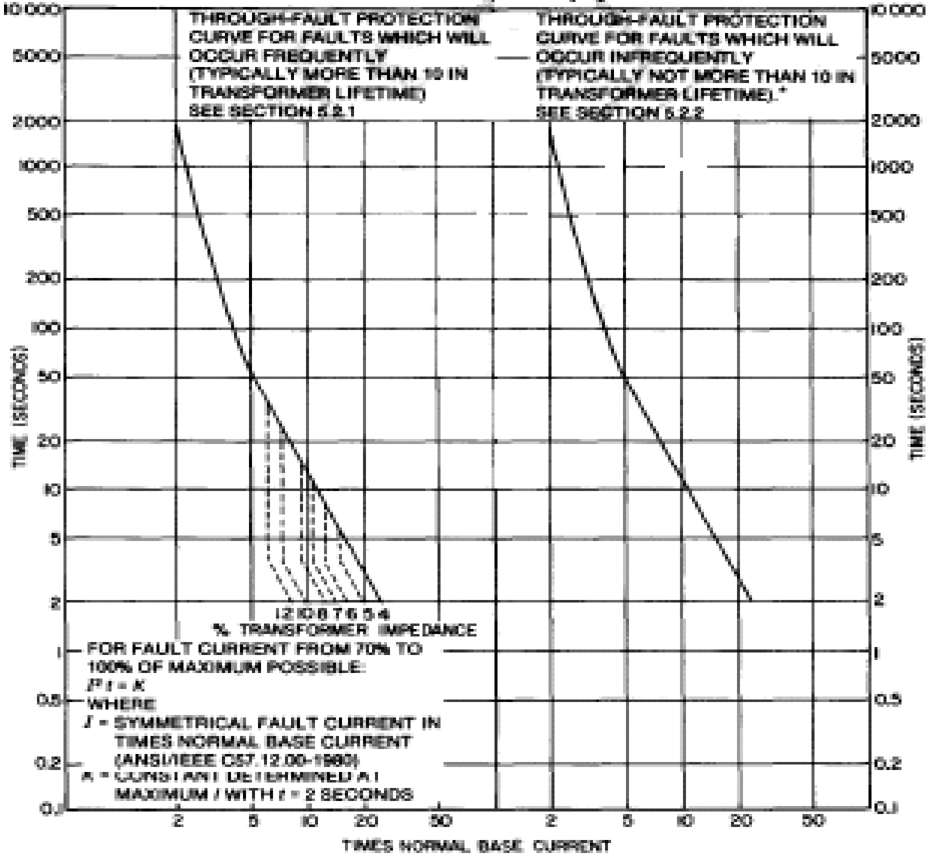
WHERE

I = SYMMETRICAL FAULT CURRENT IN TIMES NORMAL BASE CURRENT (ANSI/IEEE C57.12.00-1980 [2])

Fig 2
Category II Transformers

NOTE: Sample $I^2t = K$ curves have been plotted for selected transformer impedances as noted.

* This curve may also be used for backup protection where the transformer is exposed to frequent faults normally cleared by high-speed relaying.



THROUGH-FAULT PROTECTION CURVE FOR FAULTS WHICH WILL OCCUR FREQUENTLY (TYPICALLY MORE THAN 10 IN TRANSFORMER LIFETIME) SEE SECTION 5.2.1

THROUGH-FAULT PROTECTION CURVE FOR FAULTS WHICH WILL OCCUR INFREQUENTLY (TYPICALLY NOT MORE THAN 10 IN TRANSFORMER LIFETIME).* SEE SECTION 5.2.2

FOR FAULT CURRENT FROM 70% TO 100% OF MAXIMUM POSSIBLE:

$I^2t = K$

WHERE

I = SYMMETRICAL FAULT CURRENT IN TIMES NORMAL BASE CURRENT (ANSI/IEEE C57.12.00-1980)

K = CONSTANT DETERMINED AT MAXIMUM I WITH t = 2 SECONDS

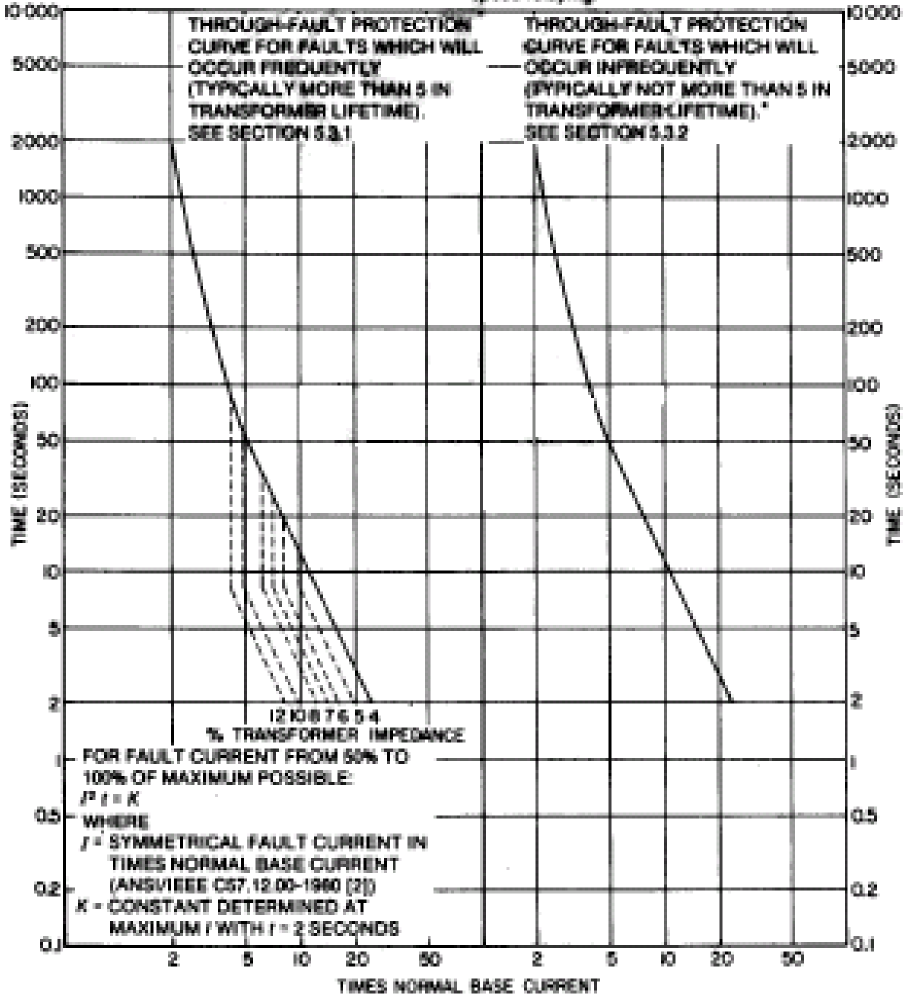
12 10 8 7 6 5 4
% TRANSFORMER IMPEDANCE
TIME (SECONDS)
10 000
5000
2000
1000
500
200
100
50
20
10
5
2
1
0.5
0.2
0.1
2
5
10
20
50
2
5
10
20
50
TIMES NORMAL BASE CURRENT

Transformer Categories III

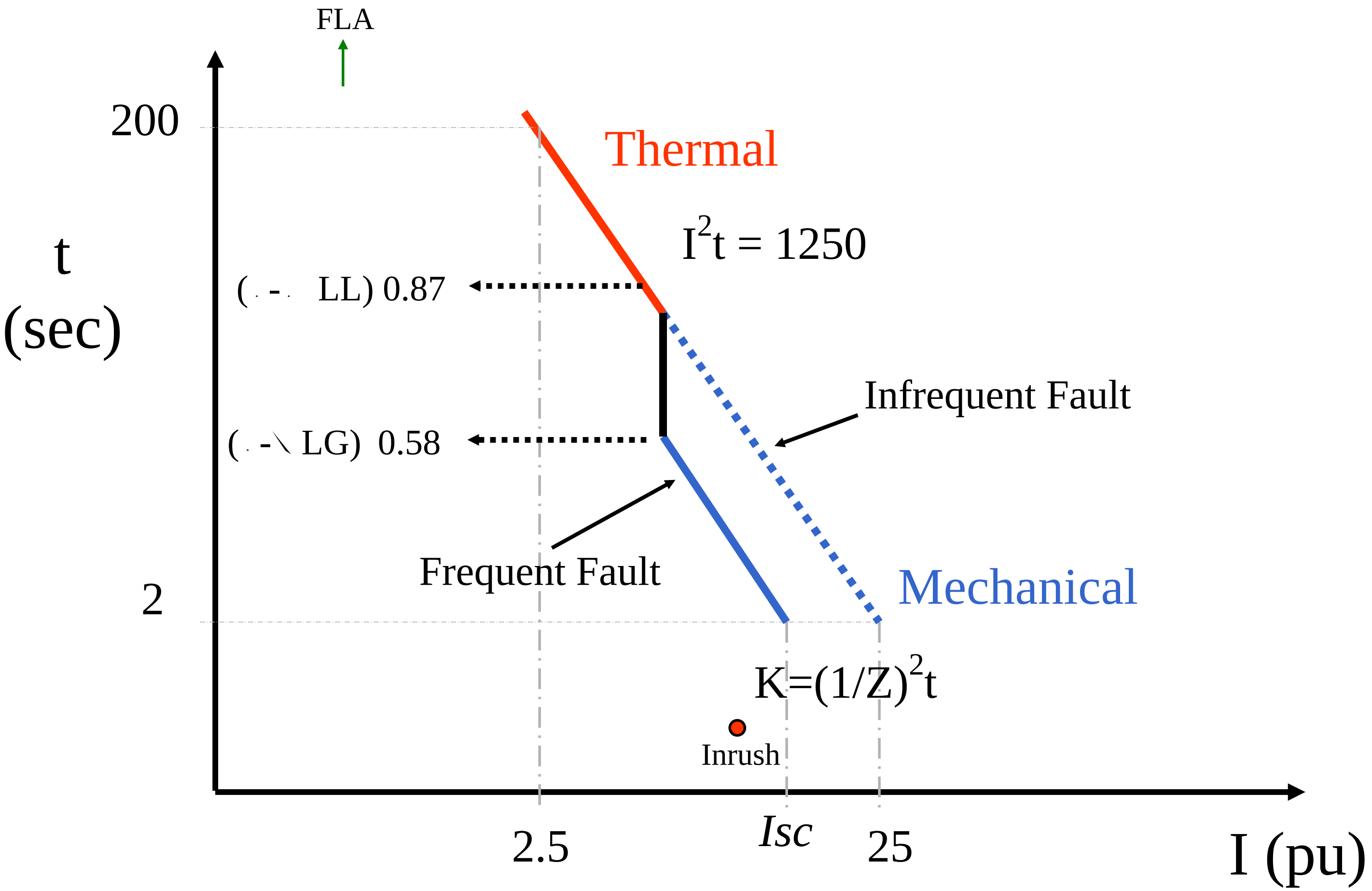
Fig 3
Category III Transformers

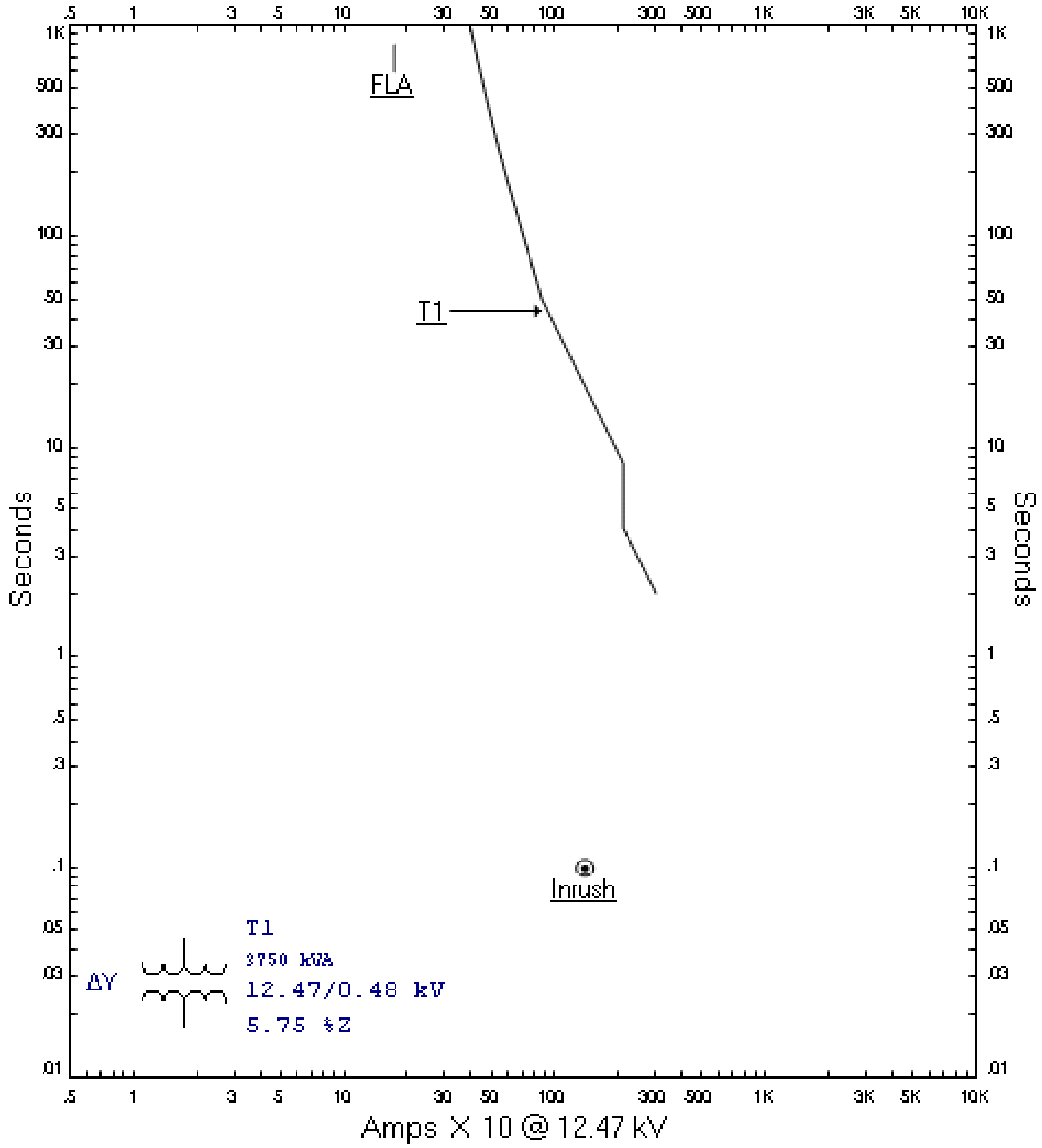
NOTE: Sample $I^2t = K$ curves have been plotted for selected transformer impedances as noted.

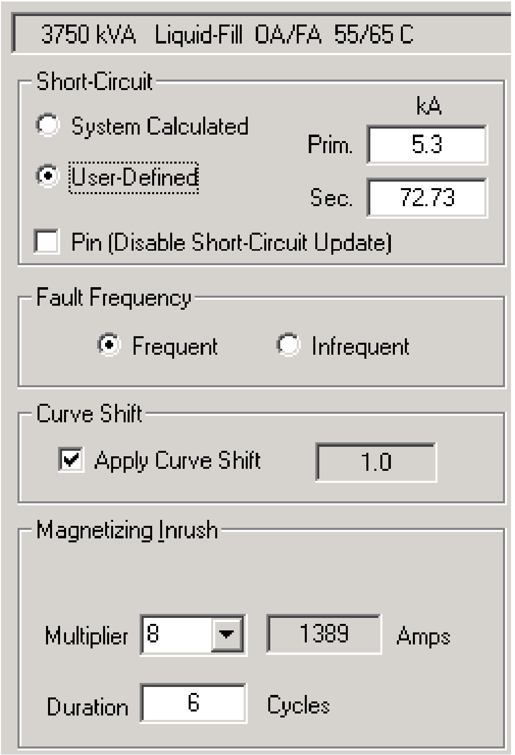
This curve may also be used for backup protection where the transformer is exposed to frequent faults normally cleared by high-speed relaying.



Transformer







3750 kVA Liquid-Fill OA/FA 55/65 C

Short-Circuit

○ System Calculated

● User-Defined

kA

Prim. 5.3

Sec. 72.73

☐ Pin (Disable Short-Circuit Update)

Fault Frequency

● Frequent ○ Infrequent

Curve Shift

☑ Apply Curve Shift 1.0

Magnetizing Inrush

Multiplier 8 1389 Amps

Duration 6 Cycles

Transformer Protection

MAXIMUM RATING OR SETTING FOR OVERCURRENT DEVICE					
	PRIMARY		SECONDARY		
	Over 600 Volts		Over 600 Volts		600 Volts or Below
Transformer Rated Impedance	Circuit Breaker Setting	Fuse Rating	Circuit Breaker Setting	Fuse Rating	Circuit Breaker Setting or Fuse Rating
Not more than 6%	600 %	300 %	300 %	250%	125% (250% supervised)
More than 6% and not more than 10%	400 %	300 %	250%	225%	125% (250% supervised)
Any Location – Non-Supervised		Table 450-3(a)			source: NEC

Transformer Protection

- Turn on or inrush current
- Internal transformer faults
- External or through faults of major magnitude
- Repeated large motor starts on the transformer. The motor represents a major portion or the transformers KVA rating.
- Harmonics
- Over current protection – Device 50/51
- Ground current protection – Device 50/51G
- Differential – Device 87
- Over or under excitation – volts/ Hz – Device 24
- Sudden tank pressure – Device 63
- Dissolved gas detection
- Oil Level
- Fans
- Oil Pumps
- Pilot wire – Device 85
- Fault withstand
- Thermal protection – hot spot, top of oil temperature, winding temperature
- Devices 26 & 49
- Reverse over current – Device 67
- Gas accumulation – Buckholz relay
- Over voltage –Device 59
- Voltage or current balance – Device 60
- Tertiary Winding Protection if supplied
- Relay Failure Scheme
- Breaker Failure Scheme

Recommended Minimum Transformer Protection

Protective system	Winding and/or power system grounded neutral grounded		Winding and/or power system neutral ungrounded	
	Up to 10 MVA	**Above 10 MVA**	**Up to 10 MVA**	**Above 10 MVA**
Differential	-	√	-	√
Time over current	√	√	√	√
Instantaneous restricted ground fault	√	√	-	-
Time delayed ground fault	√	√	-	-
Gas detection		√	-	√
Over excitation	-	√	√	√
Overheating	-	√	-	√

Question

What is ANSI Shift Curve?

Answer

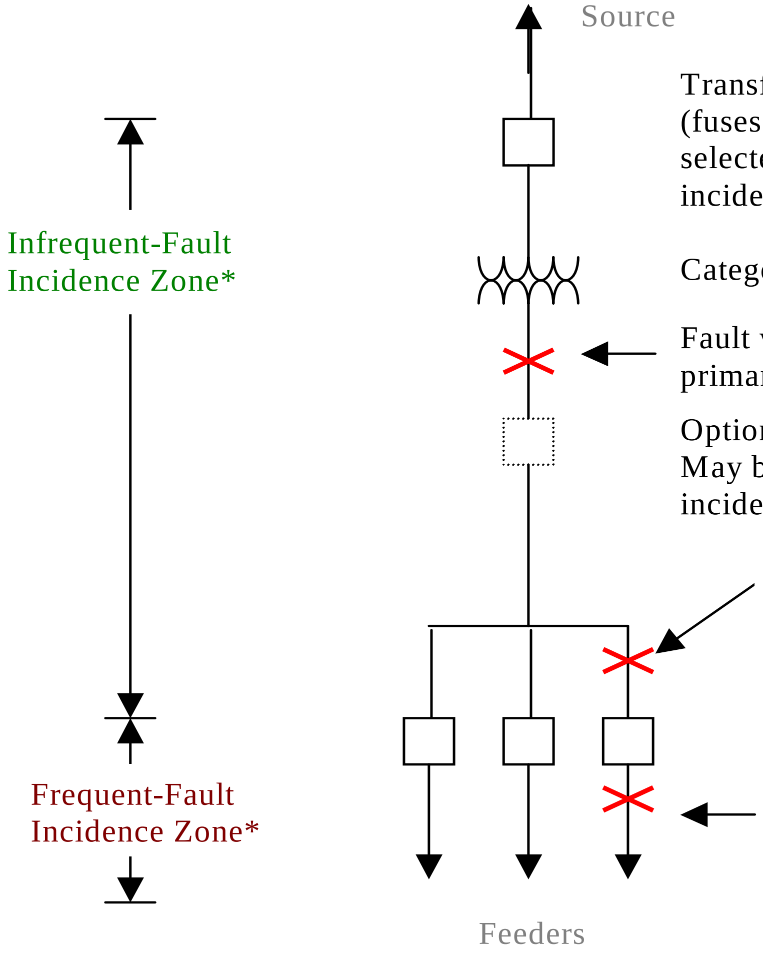
- For delta-delta connected transformers, with line-to-line faults on the secondary side, the curve must be reduced to 87% (shift to the left by a factor of 0.87)

- For delta-wye connection, with single line-to-ground faults on the secondary side, the curve values must be reduced to 58% (shift to the left by a factor of 0.58)

Question

What is meant by Frequent and Infrequent for transformers?

Infrequent Fault Incidence Zones for Category II & III Transformers


Source
Infrequent-Fault Incidence Zone*
Frequent-Fault Incidence Zone*
Feeders

Transformer primary-side protective device (fuses, relayed circuit breakers, etc.) may be selected by reference to the infrequent-fault-incidence protection curve

Category II or III Transformer

Fault will be cleared by transformer primary-side protective device

Optional main secondary –side protective device. May be selected by reference to the infrequent-fault-incidence protection curve

Fault will be cleared by transformer primary-side protective device or by optional main secondary-side protection device

Feeder protective device

Fault will be cleared by feeder protective device

* Should be selected by reference to the frequent-fault-incidence protection curve or for transformers serving industrial, commercial and institutional power systems with secondary-side conductors enclosed in conduit, bus duct, etc., the feeder protective device may be selected by reference to the infrequent-fault-incidence protection curve.

Source: IEEE C57

Motor Protection

- Standards & References
  - IEEE Std 620-1996 IEEE Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines.
  - IEEE Std 1255-2000 IEEE Guide for Evaluation of Torque Pulsations During Starting of Synchronous Motors
  - ANSI/ IEEE C37.96-2000 Guide for AC Motor Protection
  - The Art of Protective Relaying – General Electric

Motor Protection

- Motor Starting Curve
- Thermal Protection
- Locked Rotor Protection
- Fault Protection

Motor Overload Protection

(NEC Art 430-32 – Continuous-Duty Motors)

- Thermal O/L (Device 49)
- Motors with SF not less than 1.15
  - 125% of FLA
- Motors with temp. rise not over 40°C
  - 125% of FLA
- All other motors
  - 115% of FLA

Motor Protection – Inst. Pickup

$$I_{\substack{\text{LOCKED}\\\text{ROTOR}}} = \frac{1}{X_S + X_d''}$$

Recommended Instantaneous Setting:

$$\text{RELAY PICK UP} = \frac{I_{\text{PICK UP}}}{I_{\text{LOCKED ROTOR}}} * 1.6 \text{ TO } 2$$

If the recommended setting criteria cannot be met, or where more sensitive protection is desired, the in-stantaneous relay (or a second relay) can be set more sensitively if delayed by a timer. This permits the asymmetrical starting component to decay out. A typical setting for this is:

$$\text{RELAY PICK UP} = \frac{I_{\text{PICK UP}}}{I_{\text{LOCKED ROTOR}}} * 1.2 \text{ TO } 1.2$$

with a time delay of 0.10 s (six cycles at 60 Hz)

Locked Rotor Protection

- Thermal Locked Rotor (Device 51)
- Starting Time (TS < TLR)
- LRA
  - LRA sym
  - LRA asym (1.5-1.6 x LRA sym) + 10% margin

Fault Protection

(NEC Art / Table 430-52)

- Non-Time Delay Fuses
  - – 300% of FLA
- Dual Element (Time-Delay Fuses)
  - – 175% of FLA
- Instantaneous Trip Breaker
  - – 800% - 1300% of FLA*
- Inverse Time Breakers
  - – 250% of FLA

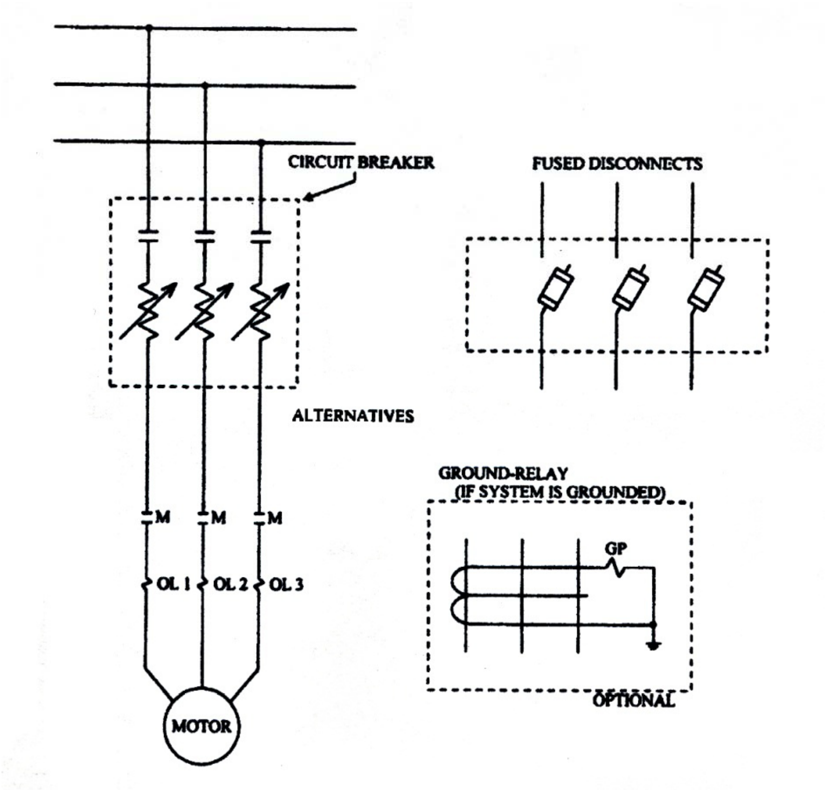
**can be set up to 1700% for Design B (energy efficient) Motor*

Low Voltage Motor Protection

- Usually pre-engineered (selected from Catalogs)
- Typically, motors larger than 2 Hp are protected by combination starters
- Overload / Short-circuit protection

Low-voltage Motor

Ratings	**Range of ratings**	
Continuous amperes	9-250	—
Nominal voltage (V)	240-600	—
Horsepower	1.5-1000	—
Starter size (NEMA)	—	00-9
Types of protection	**Quantity**	**NEMA designation**
Overload: overload relay elements	3	OL
Short circuit: circuit breaker current trip elements	3	CB
Fuses	3	FU
Undervoltage: inherent with integral control supply and three-wire control circuit	—	—
Ground fault (when speci-fied): ground relay with toroidal CT	—	—


CIRCUIT BREAKER
FUSED DISCONNECTS
ALTERNATIVES
GROUND-RELAY
(IF SYSTEM IS GROUNDED)
GP
OPTIONAL
M
M
M
OL 1
OL 2
OL 3
MOTOR

Low-voltage motor controller

Minimum Required Sizes of a NEMA Combination Motor Starter System

MOTOR HP	460V NEC FLC	STARTER SIZE	MINIMUM SIZE GROUNDING CONDUCTOR FOR A 50 % CURRENT CAPACITY	MAXIMUM CONDUCTOR LENGTH FOR ABOVE AND BELOW GROUND CONDUIT SYSTEMS. ABOVE GROUND SYSTEMS HAVE DIRECT SOLAR EXPOSURE. 75^0 C CONDUCTOR TEMPERATURE, 45^0 C AMBIENT				CIRCUIT BREAKER SIZE			FUSE SIZE CLASS J FUSE
				MINIMUM WIRE SIZE	MAXIMUM LENGTH FOR 1% VOLTAGE DROP	NEXT LARGEST WIRE SIZE ***USE NEXT LARGER GROUND CONDUCTOR***	MAXIMUM LENGTH FOR 1% VOLTAGE DROP WITH LARGER WIRE	250%	200%	150%	
1	2.1	0	12	12	759	10	1251	15	15	**15**	5
1½	3	0	12	12	531	10	875	15	15	**15**	6
2	3.4	0	12	12	468	10	772	15	15	**15**	7
3	4.8	0	12	12	332	10	547	20	20	**15**	10
5	7.6	0	12	12	209	10	345	20	20	**15**	15
7½	11	1	12	10	144	8	360	**30**	25	20	20
10	14	1	10	8	283	6	439	35	**30**	25	30
15	21	2	10	8	189	6	292	50	**40**	30	45
20	27	2	10	6	227	4	347	70	**50**	40	60
25	34	2	8	4	276	2	407	80	**70**	50	70
30	40	3	6	2	346	2/0	610	100	**70**	60	90
40	52	3	6	2	266	2/0	469	150	110	**90**	110
50	65	3	2	2/0	375	4/0	530	175	150	**100**	125
60	77	4	2	2/0	317	4/0	447	200	175	**125**	150
75	96	4	2	4/0	358	250	393	250	200	**150**	200
100	124	4	1	250	304	350	375	350	250	**200**	250
125	156	5	2/0	350	298	500	355	400	300	**250**	350
150	180	5	4/0	500	307	750	356	450	350	**300**	400

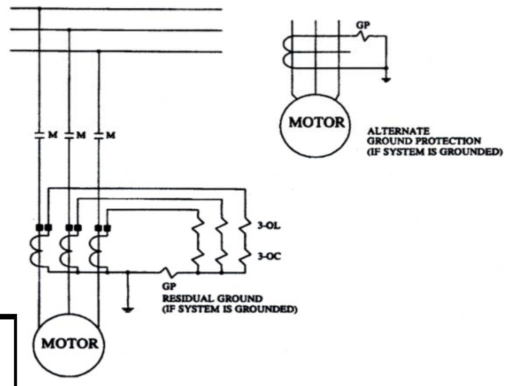
Required Data - Protection of a Medium Voltage Motor

- Rated full load current
- Service factor
- Locked rotor current
- Maximum locked rotor time (thermal limit curve) with the motor at ambient and/or operating temperature
- Minimum no load current
- Starting power factor
- Running power factor
- Motor and connected load accelerating time
- System phase rotation and nominal frequency
- Type and location of resistance temperature devices (RTDs), if used
- Expected fault current magnitudes
- First ½ cycle current
- Maximum motor starts per hour

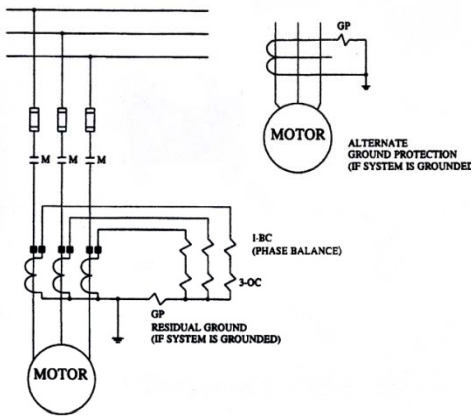
Medium-Voltage Class E Motor Controller

Ratings	Class EI (without fuses)	Class E2 (with fuses)
Nominal system voltage	2300-6900	2300-6900
Horsepower	0-8000	0-8000
Symmetrical MVA interrupting capacity at nominal system voltage	25-75	160-570
Types of Protective Devices	**Quantity**	**NEMA Designation**
Overload, or locked Rotor, or both: Thermal overload relay TOC relay IOC relay plus time delay	 3 3 3	OL OC TR/O
Thermal overload relay	3	OL
TOC relay	3	OC
IOC relay plus time delay	3	TR/OC
Short Circuit:		
Fuses, Class E2	3	FU
IOC relay, Class E1	3	OC
Ground Fault		
TOC residual relay	1	GP
Overcurrent relay with toroidal CT	1	GP

Phase Balance		
Current balance relay	1	BC
Negative-sequence voltage relay (per bus), or both	1	—
Undervoltage: Inherent with integral control supply and three-wire control circuit, when voltage falls suffi-ciently to permit the contractor to open and break the seal-in circuit	—	UV
Temperature: Temperature relay, operating from resistance sensor or ther-mocouple in stator winding	—	OL

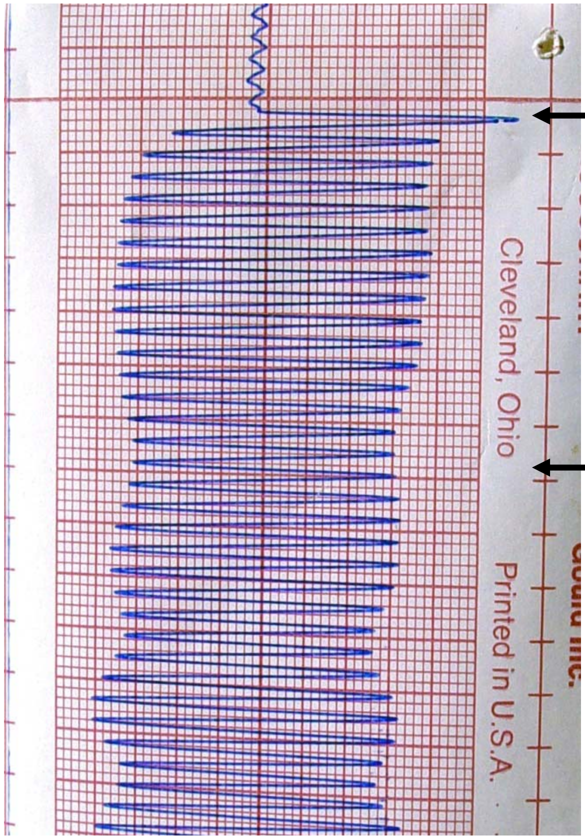

GP
MOTOR
ALTERNATE GROUND PROTECTION (IF SYSTEM IS GROUNDED)
M M M
3-OL
3-OC
GP RESIDUAL GROUND (IF SYSTEM IS GROUNDED)
MOTOR

NEMA Class E1 medium voltage starter


GP
MOTOR
ALTERNATE GROUND PROTECTION (IF SYSTEM IS GROUNDE
M M M
1-BC (PHASE BALANCE)
3-OC
GP RESIDUAL GROUND (IF SYSTEM IS GROUNDED)
MOTOR

NEMA Class E2 medium voltage starter

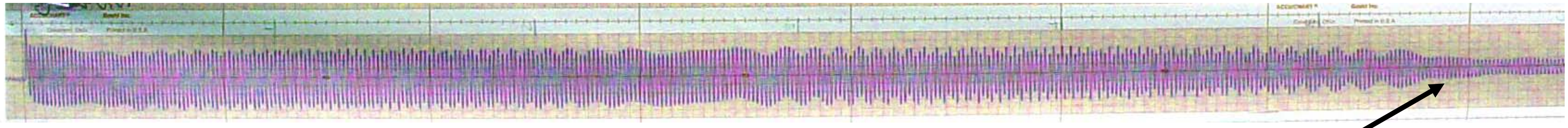
Starting Current of a 4000Hp, 12 kV, 1800 rpm Motor



First half cycle current showing current offset.

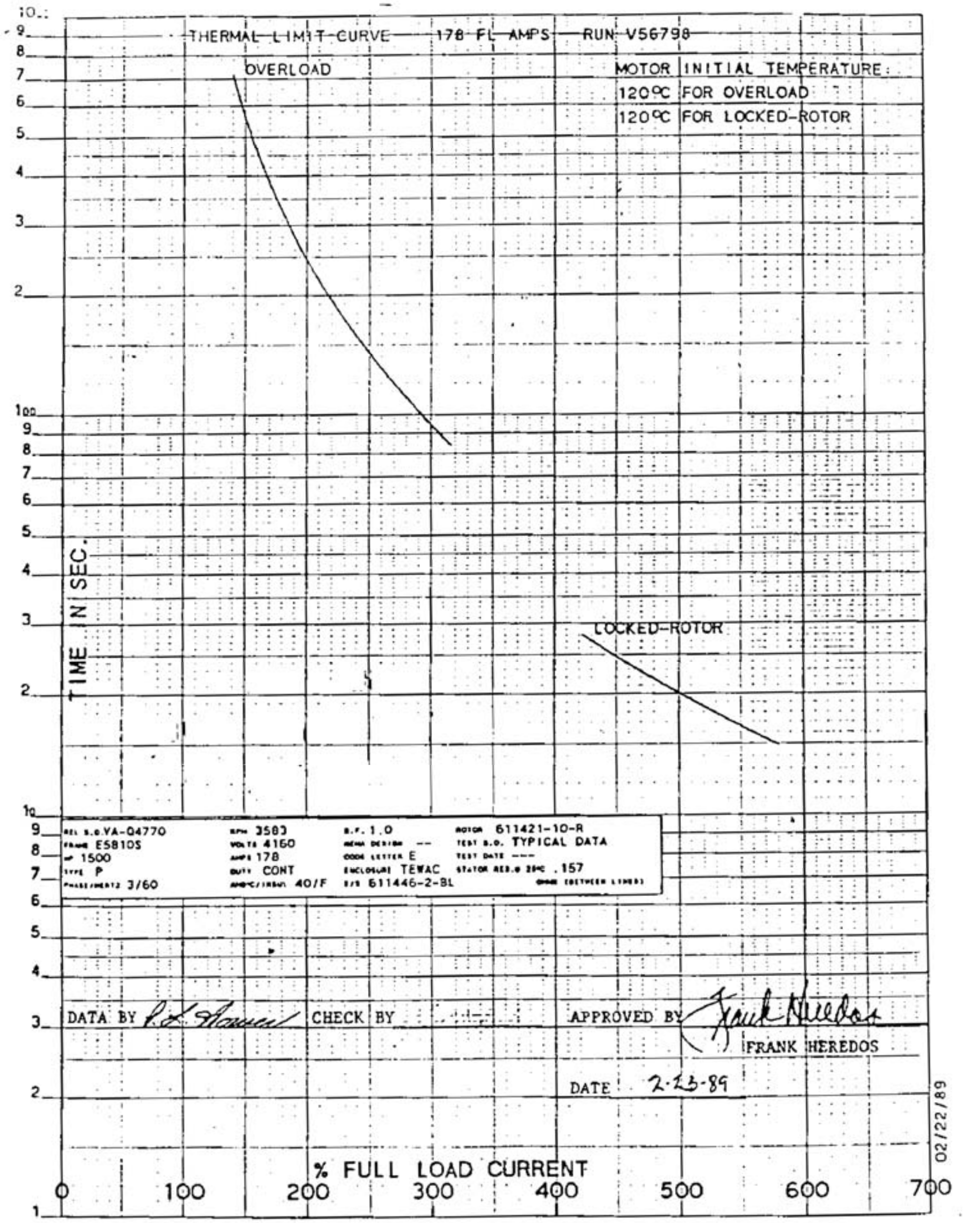
Beginning of run up current showing load torque pulsations.

Starting Current of a 4000Hp, 12 kV, 1800 rpm Motor - Oscillographs



Motor pull in current showing motor reaching synchronous speed

Thermal Limit Curve



REL S.O. VA-04770
FRAME E5810S
HP 1500
TYPE P
PHASES/HERTZ 3/60

RPM 3583
VOLTS 4160
AMPS 178
DUTY CONT
AMB°C/INSUL 40/F

S.F. 1.0
NEMA DESIGN --
CODE LETTER E
ENCLOSURE TEWAC
S/N 611446-2-BL

ROTOR 611421-10-R
TEST S.O. TYPICAL DATA
TEST DATE ---
STATOR RES.@ 25°C .157
OHMS (BETWEEN LINES)

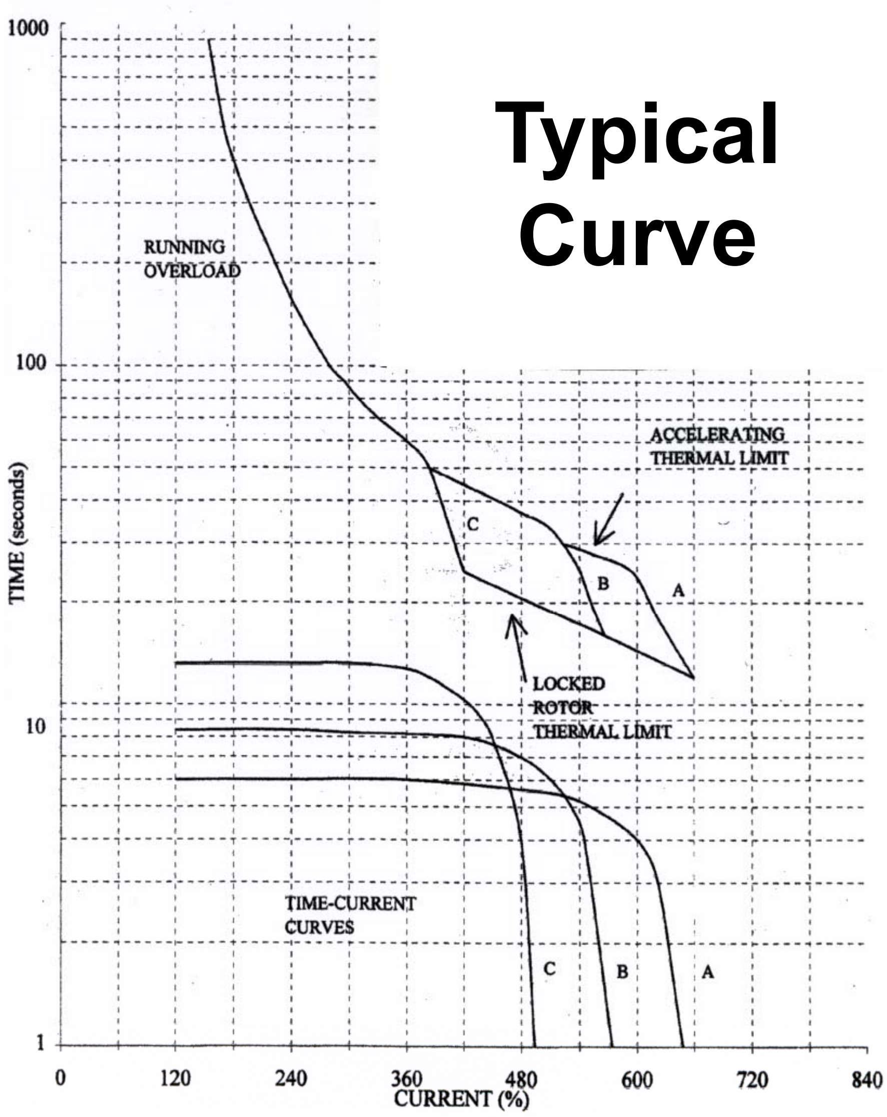
DATA BY

CHECK BY

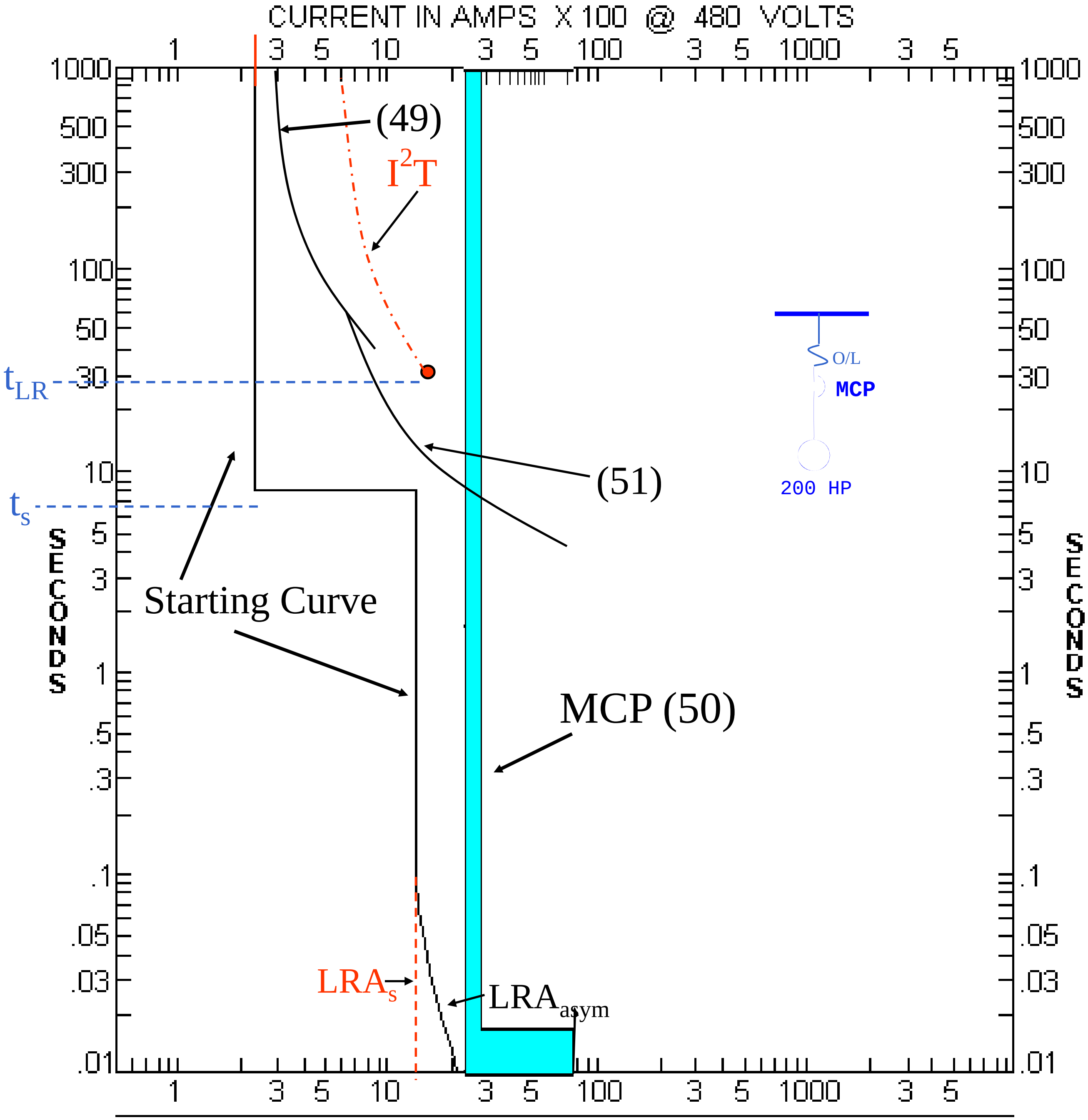
APPROVED BY Frank Heredos
FRANK HEREDOS

DATE 2-23-89

Thermal Limit Curve



Typical Curve


CURRENT IN AMPS X 100 @ 480 VOLTS
1
3
5
10
3
5
100
3
5
1000
3
5
1000
500
300
100
50
30
10
5
3
1
.5
.3
.1
.05
.03
.01
SECONDS
(49)
I^2T
t_{LR}
t_s
(51)
Starting Curve
MCP (50)
LRA_s
LRA_{asym}
O/L
MCP
200 HP

Protective Devices

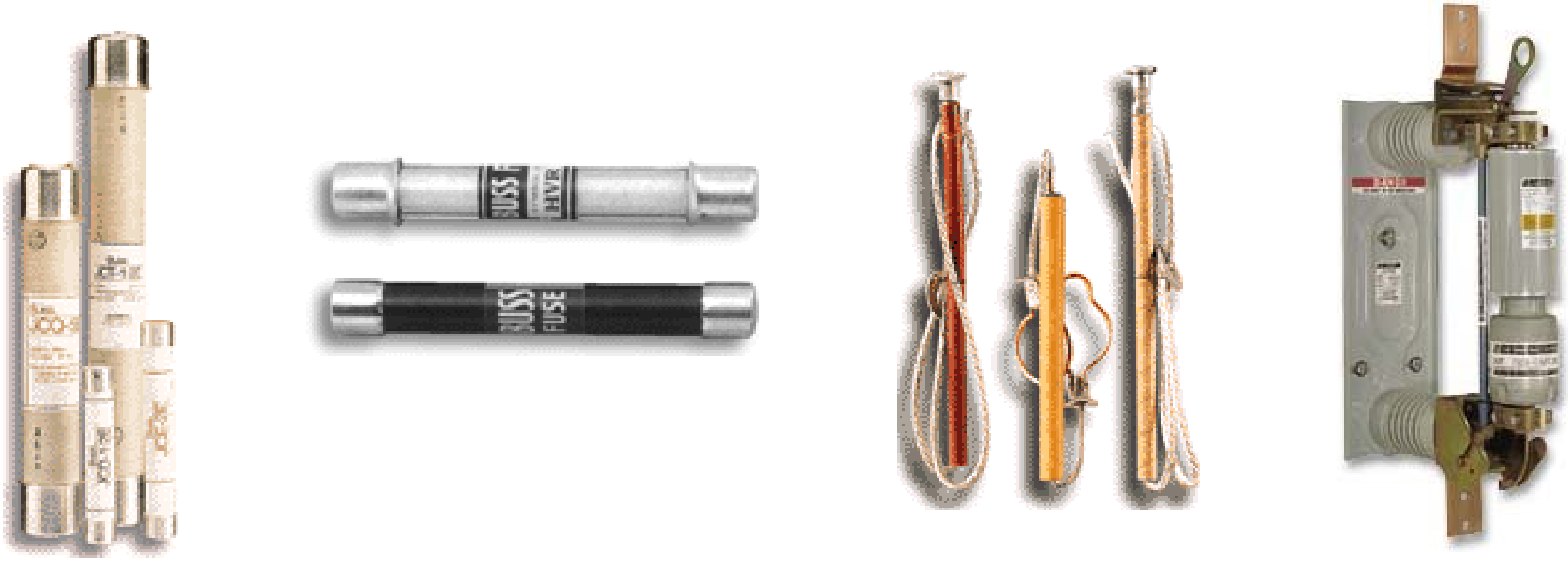
- Fuse
- Overload Heater
- Thermal Magnetic
- Low Voltage Solid State Trip
- Electro-Mechanical
- Motor Circuit Protector (MCP)
- Relay (50/51 P, N, G, SG, 51V, 67, 49, 46, 79, 21, …)

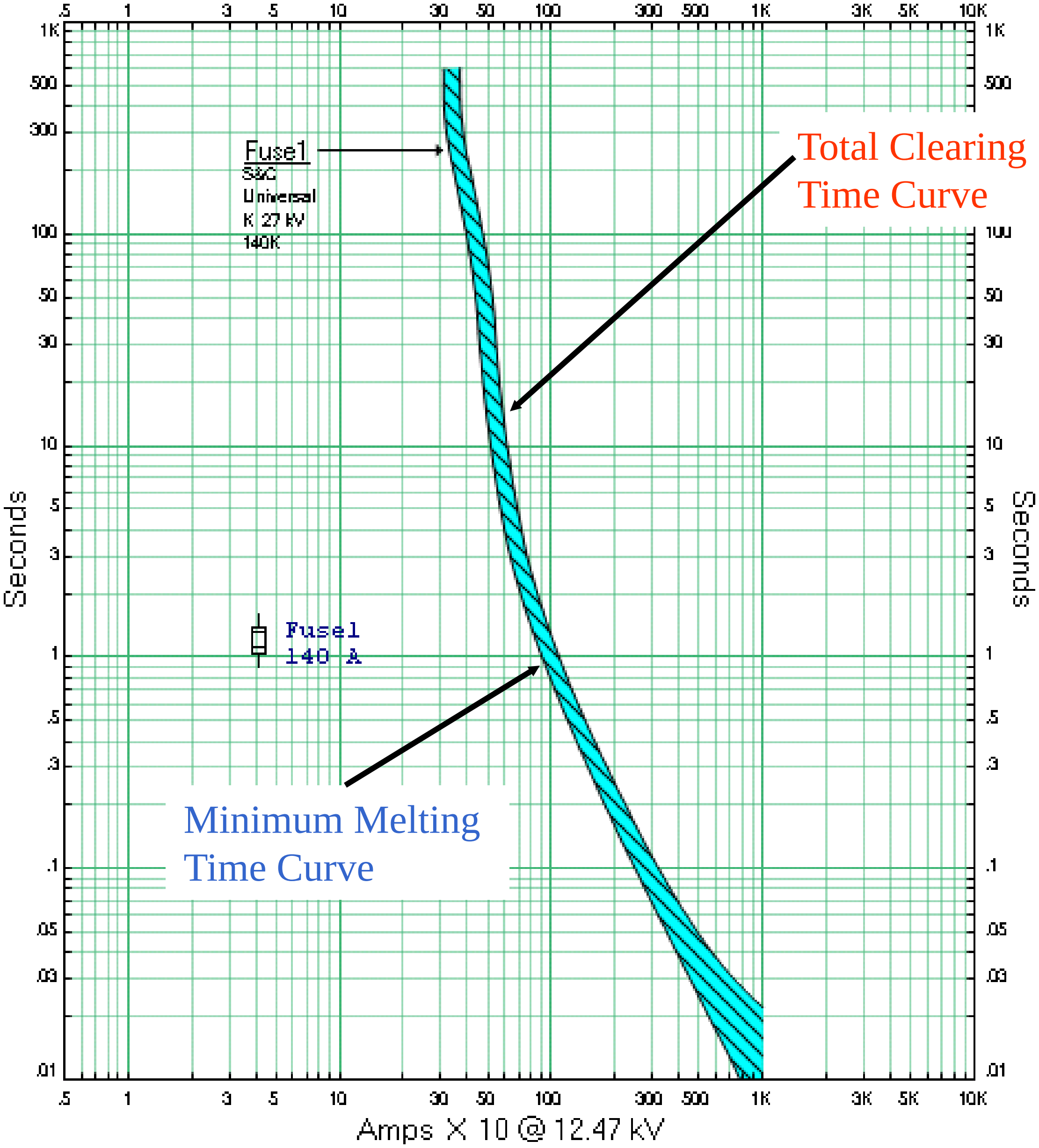
Fuse (Power Fuse)

- Non Adjustable Device (unless electronic)
- Continuous and Interrupting Rating
- Voltage Levels (Max kV)
- Interrupting Rating (sym, asym)
- Characteristic Curves
  - Min. Melting
  - Total Clearing
- Application (rating type: R, E, X, …)

Fuse Types

- Expulsion Fuse (Non-CLF)
- Current Limiting Fuse (CLF)
- Electronic Fuse *(S&C Fault Fiter)*





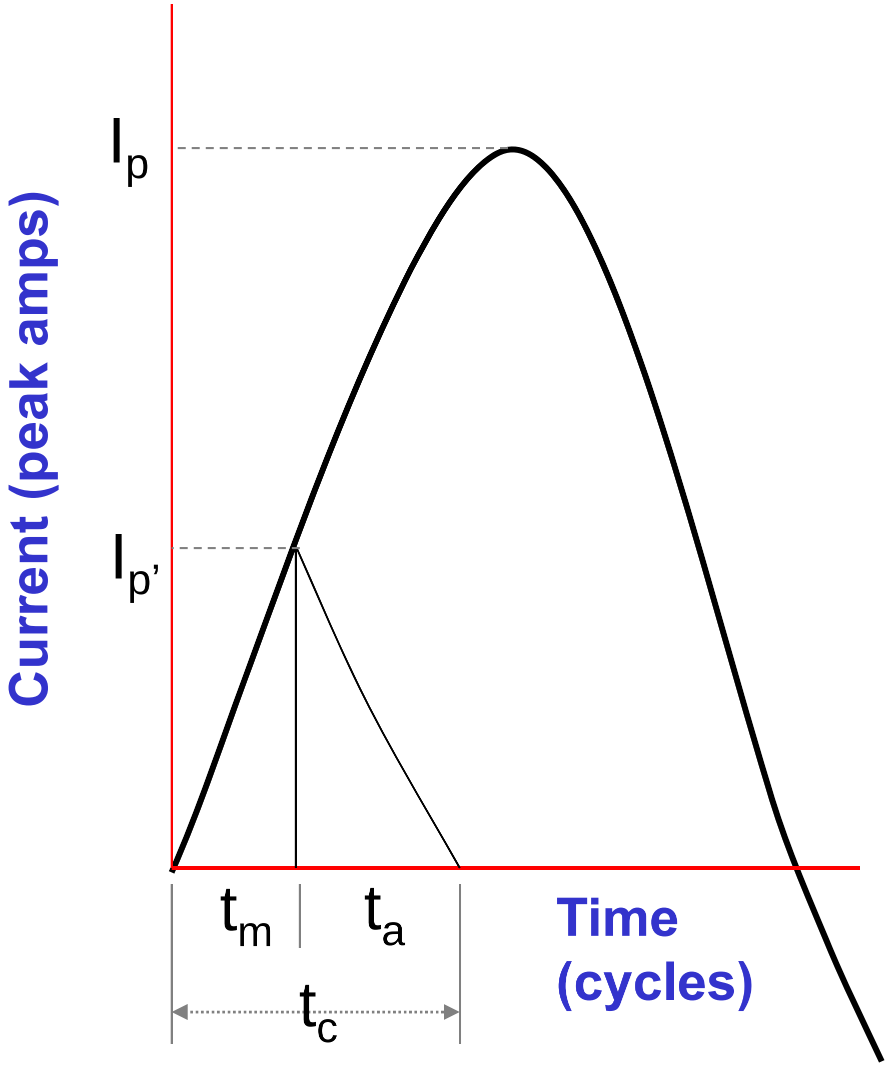
Total Clearing Time Curve

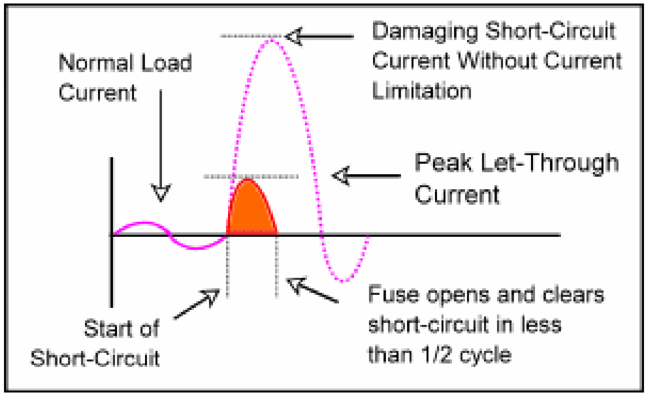
Minimum Melting Time Curve

Current Limiting Fuse (CLF)

- Limits the peak current of short-circuit
- Reduces magnetic stresses (mechanical damage)
- Reduces thermal energy

Current Limiting Action





Normal Load Current
Damaging Short-Circuit Current Without Current Limitation
Peak Let-Through Current
Start of Short-Circuit
Fuse opens and clears short-circuit in less than 1/2 cycle

$t_a = t_c - t_m$

t_a = Arcing Time

t_m = Melting Time

t_c = Clearing Time

I_p = Peak Current

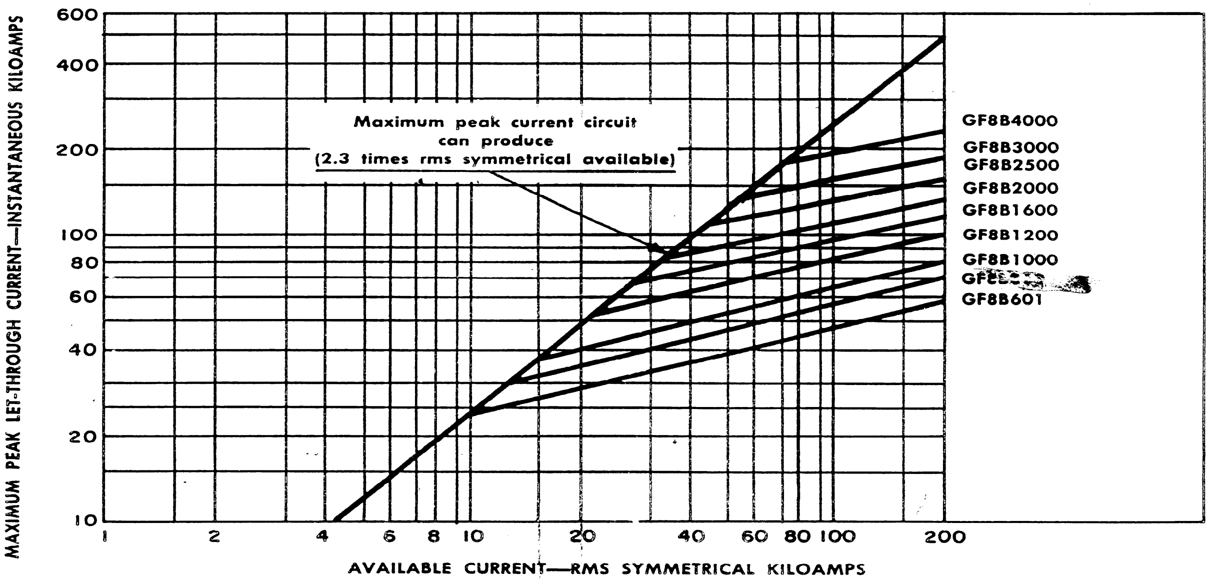
$I_{p'}$ = Peak Let-thru Current

LOW-VOLTAGE CURRENT-LIMITING FUSE

CLF® FUSE—CLASS L

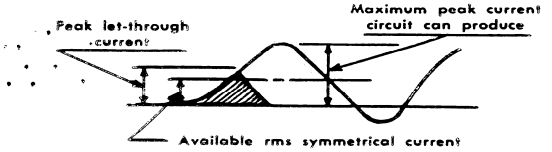
600 Volts

Peak Let-through Current Characteristics



Data taken under following test conditions:

- 600 volts, 60 Hertz system
- Single phase
- Power factor less than 15%
- Condition of asymmetry to produce maximum let-through current

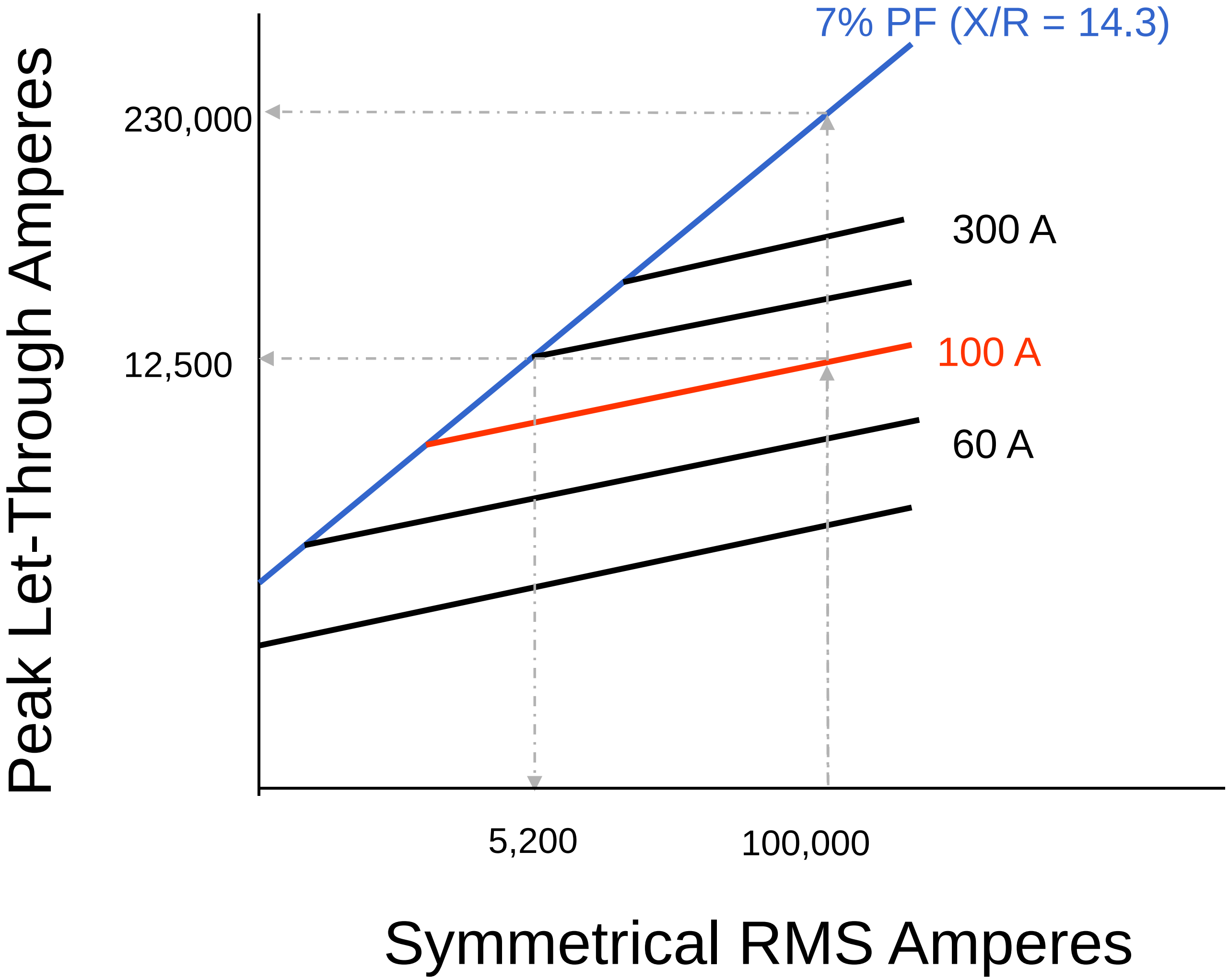

Peak let-through current
Maximum peak current circuit can produce
Available rms symmetrical current

GENERAL ELECTRIC COMPANY
POWER SYSTEMS MANAGEMENT BUSINESS DEPARTMENT
PHILADELPHIA, PENNSYLVANIA 19142

4-74 (15M)

GENERAL ELECTRIC

Let-Through Chart



Fuse

Generally:

- CLF is a better short-circuit protection
- Non-CLF (expulsion fuse) is a better Overload protection
- Electronic fuses are typically easier to coordinate due to the electronic control adjustments

Selectivity Criteria

Typically:

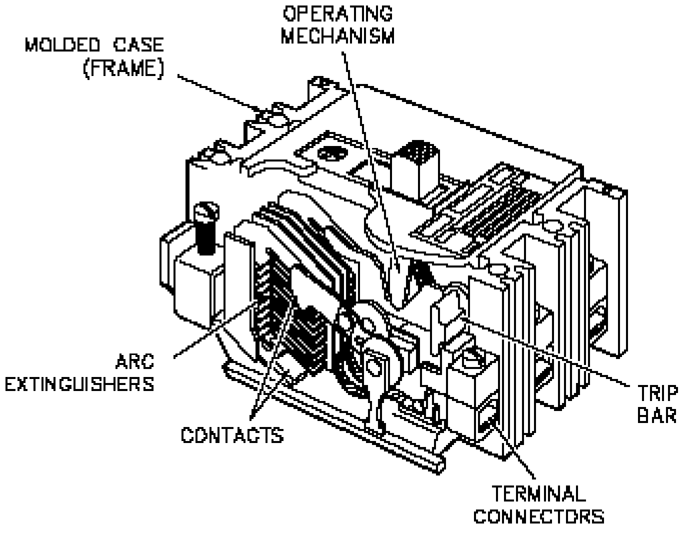
- Non-CLF: 140% of full load
- CLF: 150% of full load
- Safety Margin: 10% applied to Min Melting (consult the fuse manufacturer)

Molded Case CB

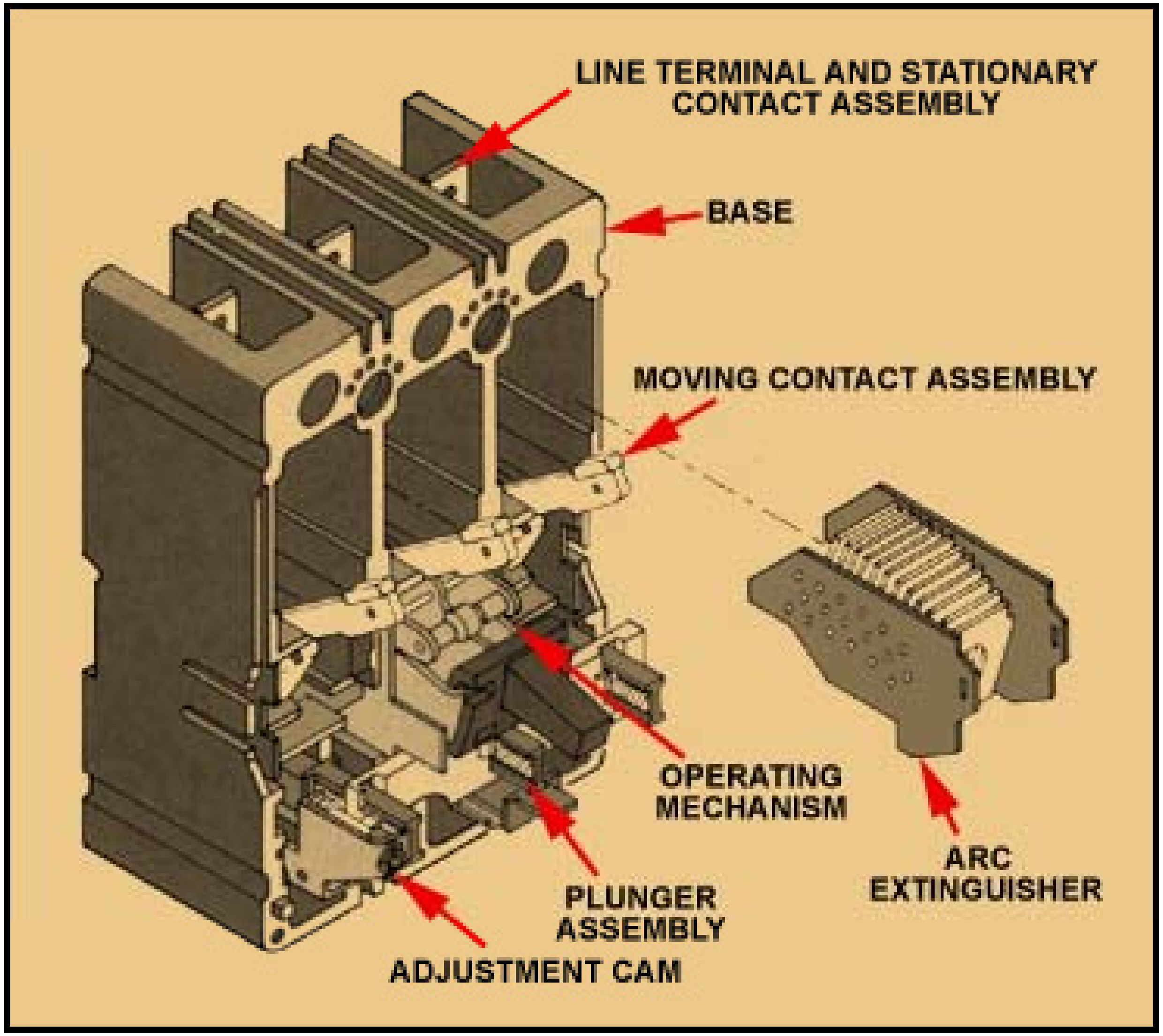
- Thermal-Magnetic
- Magnetic Only
- Motor Circuit Protector (MCP)
- Integrally Fused (Limiters)
- Current Limiting
- High Interrupting Capacity
- Non-Interchangeable Parts
- Insulated Case (Interchange Parts)

Types

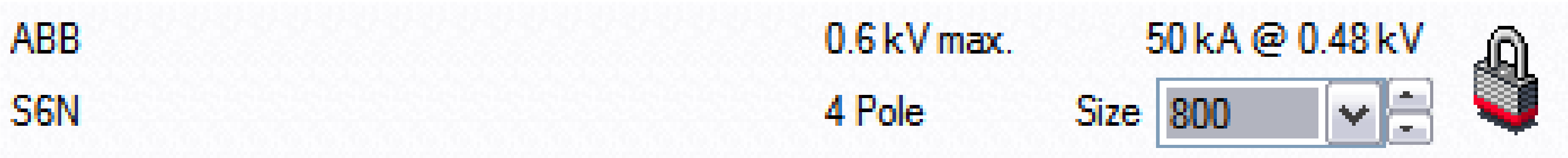
- Frame Size
- Poles
- Trip Rating
- Interrupting Capability
- Voltage


OPERATING MECHANISM
MOLDED CASE (FRAME)
ARC EXTINGUISHERS
CONTACTS
TRIP BAR
TERMINAL CONNECTORS

MCCB


LINE TERMINAL AND STATIONARY CONTACT ASSEMBLY
BASE
MOVING CONTACT ASSEMBLY
OPERATING MECHANISM
ARC EXTINGUISHER
PLUNGER ASSEMBLY
ADJUSTMENT CAM

MCCB with SST Device



ABB

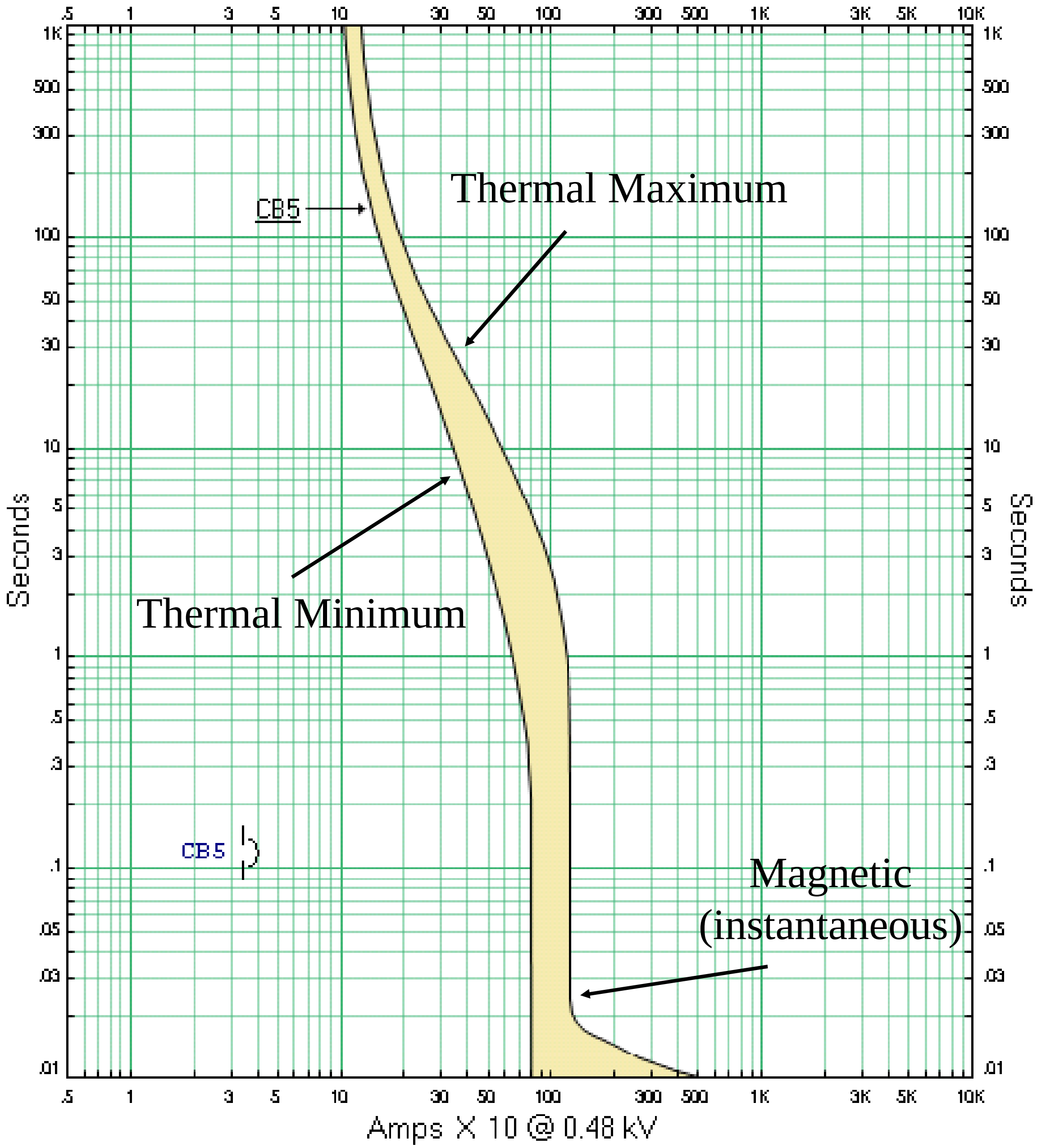
S6N

0.6 kV max.

4 Pole

50 kA @ 0.48 kV

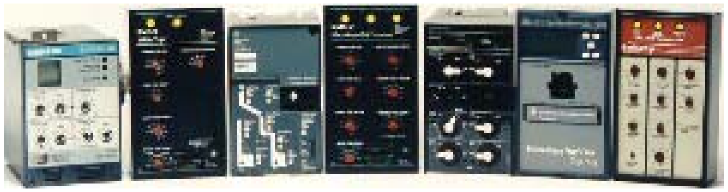
Size 800

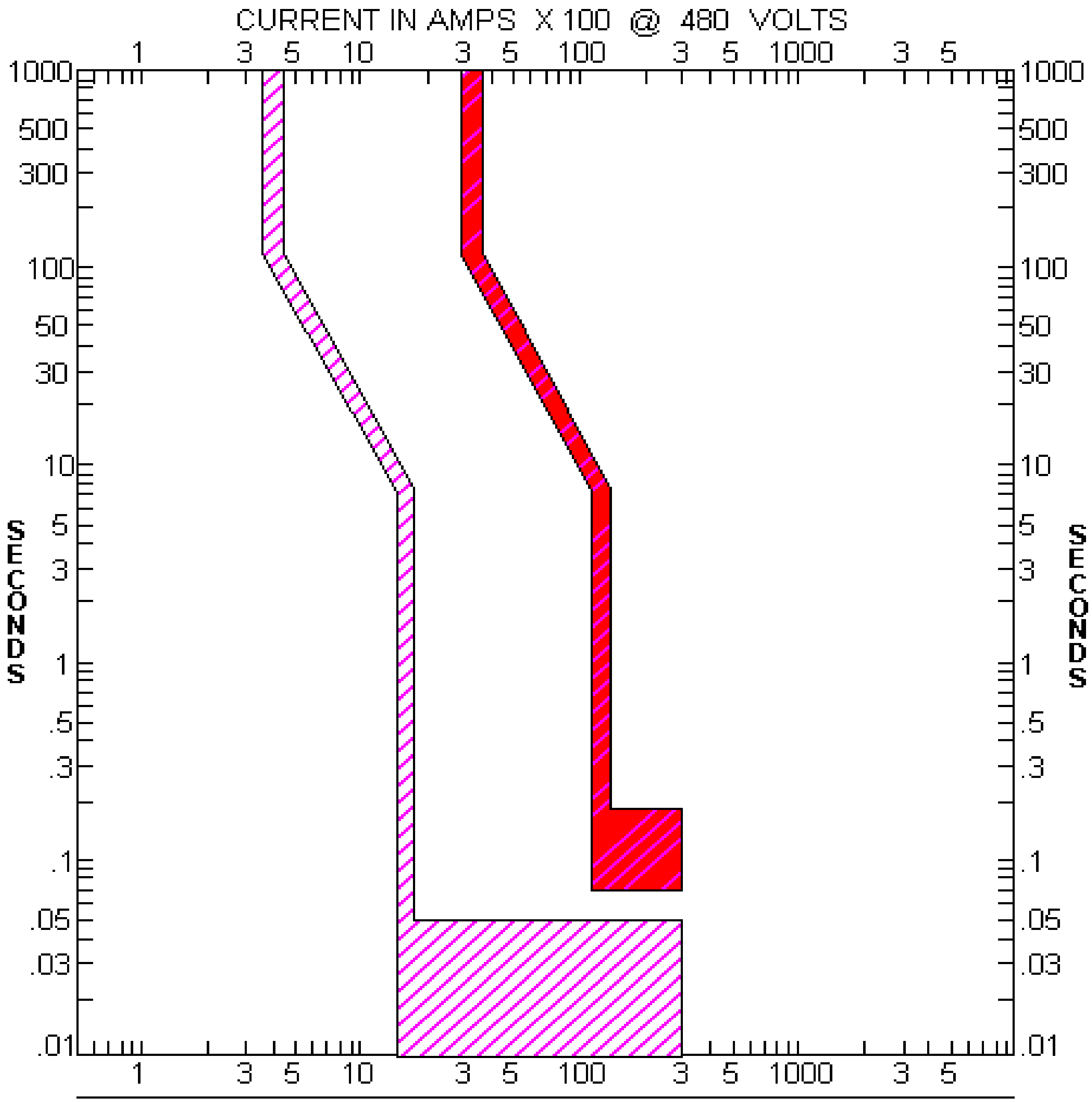


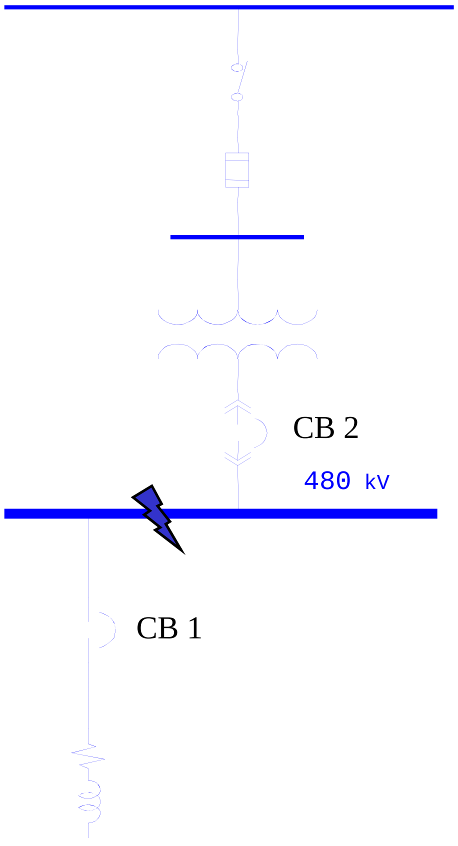
Thermal Maximum
Thermal Minimum
Magnetic (instantaneous)
CB5
CB5
Seconds
Amps X 10 @ 0.48 kV
.5
1
3
5
10
30
50
100
300
500
1K
3K
5K
10K
1K
500
300
100
50
30
10
5
3
1
.5
.3
.1
.05
.03
.01

LVPCB

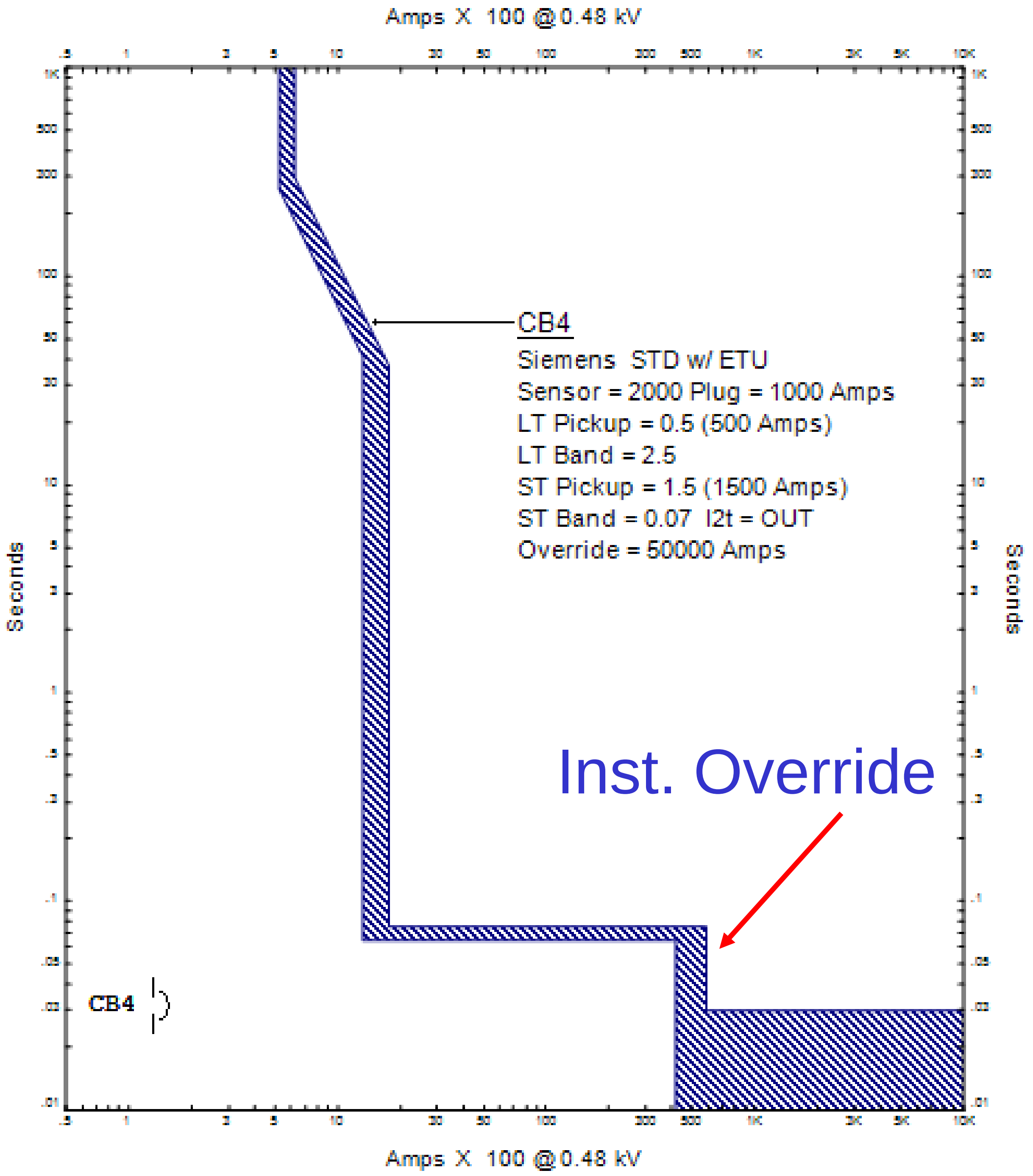
- Voltage and Frequency Ratings
- Continuous Current / Frame Size / Sensor
- Interrupting Rating
- Short-Time Rating (30 cycle)
- Fairly Simple to Coordinate
- Phase / Ground Settings
- Inst. Override




CURRENT IN AMPS X 100 @ 480 VOLTS
1
3
5
10
3
5
100
3
5
1000
3
5
SECONDS
1000
500
300
100
50
30
10
5
3
1
.5
.3
.1
.05
.03
.01


CB 2
480 kV
CB 1

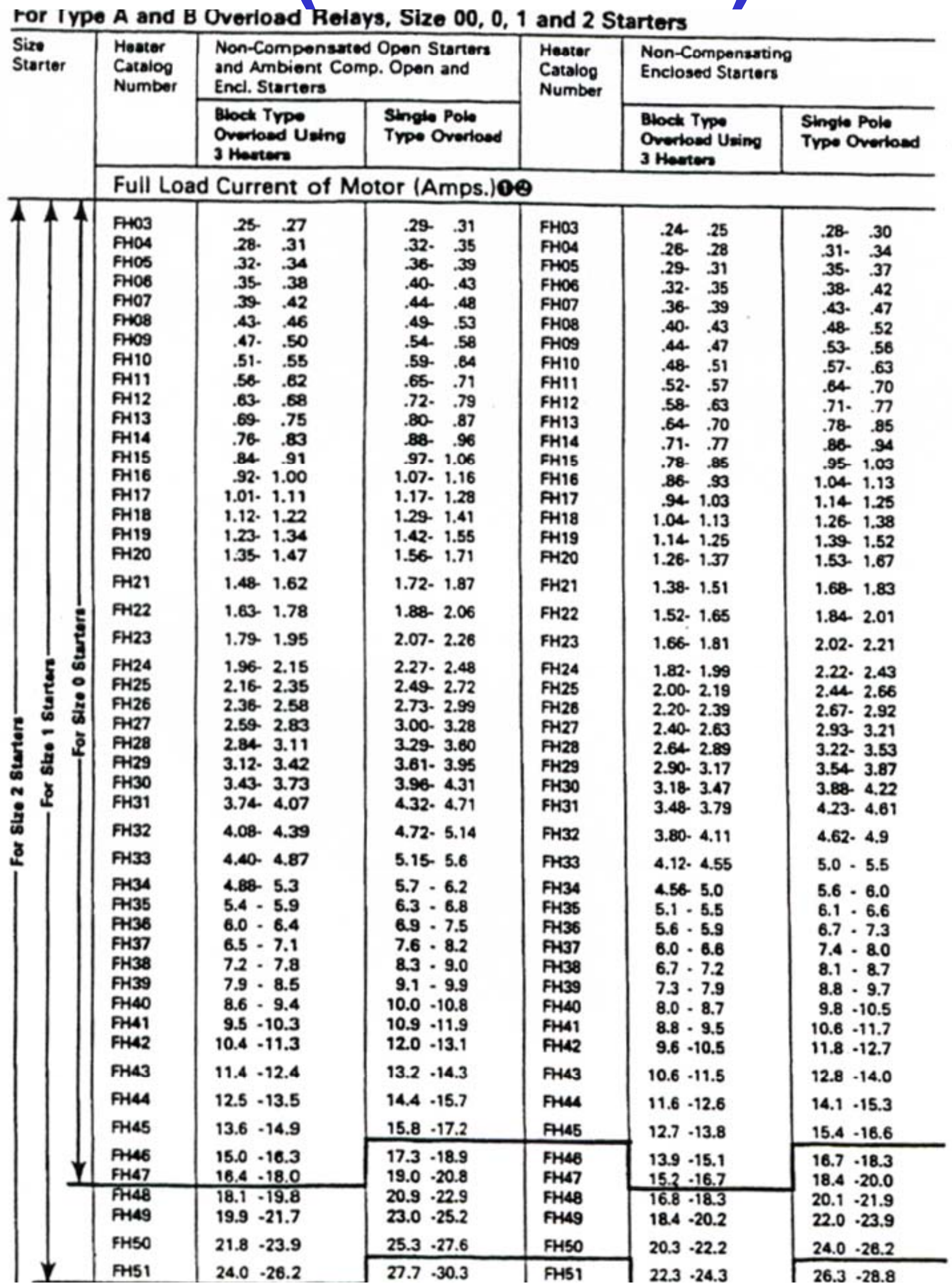
I_f =30 kA


Amps X 100 @ 0.48 kV
.5
1
3
5
10
30
50
100
300
500
1K
3K
5K
10K
1K
500
300
100
50
30
10
5
3
1
.5
.3
.1
.05
.03
.01
Seconds
CB4
Siemens STD w/ ETU
Sensor = 2000 Plug = 1000 Amps
LT Pickup = 0.5 (500 Amps)
LT Band = 2.5
ST Pickup = 1.5 (1500 Amps)
ST Band = 0.07 I2t = OUT
Override = 50000 Amps
CB4
Inst. Override

Overload Relay / Heater

- Motor overload protection is provided by a device that models the temperature rise of the winding
- When the temperature rise reaches a point that will damage the motor, the motor is de-energized
- Overload relays are either bimetallic, melting alloy or electronic

Overload Heater (Mfr. Data)

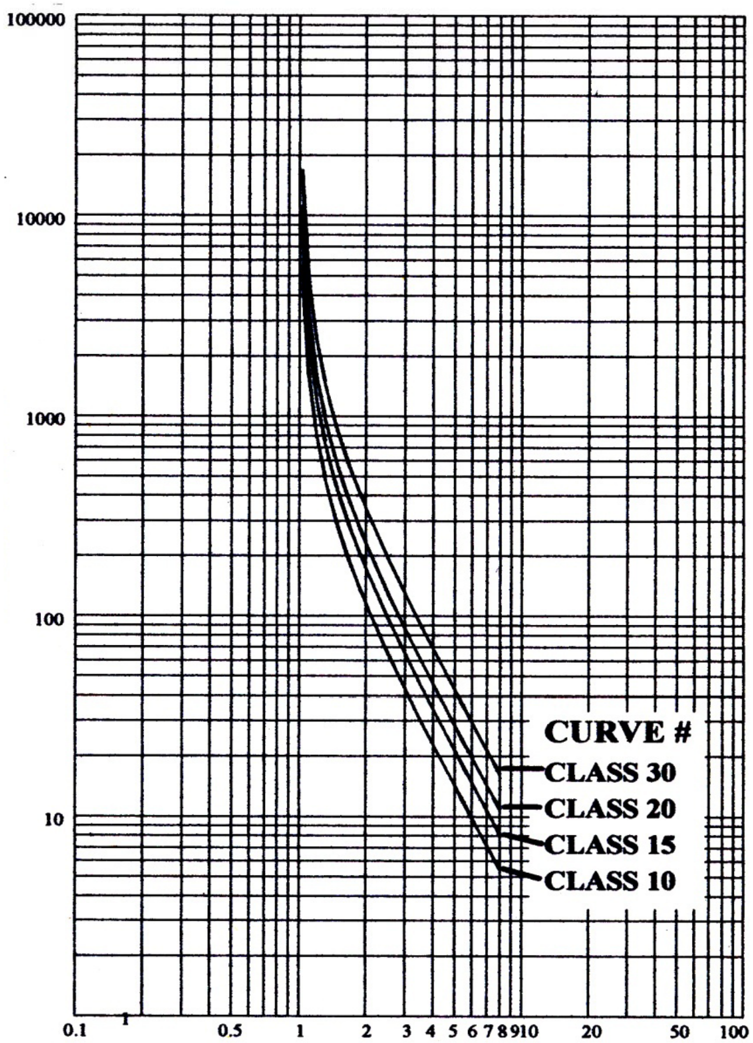


For Type A and B Overload Relays, Size 00, 0, 1 and 2 Starters

Size Starter	Heater Catalog Number	Non-Compensated Open Starters and Ambient Comp. Open and Encl. Starters		Heater Catalog Number	Non-Compensating Enclosed Starters	
		Block Type Overload Using 3 Heaters	Single Pole Type Overload		Block Type Overload Using 3 Heaters	Single Pole Type Overload
	Full Load Current of Motor (Amps.)❶❷					
For Size 0 Starters For Size 1 Starters For Size 2 Starters	FH03	.25- .27	.29- .31	FH03	.24- .25	.28- .30
	FH04	.28- .31	.32- .35	FH04	.26- .28	.31- .34
	FH05	.32- .34	.36- .39	FH05	.29- .31	.35- .37
	FH06	.35- .38	.40- .43	FH06	.32- .35	.38- .42
	FH07	.39- .42	.44- .48	FH07	.36- .39	.43- .47
	FH08	.43- .46	.49- .53	FH08	.40- .43	.48- .52
	FH09	.47- .50	.54- .58	FH09	.44- .47	.53- .56
	FH10	.51- .55	.59- .64	FH10	.48- .51	.57- .63
	FH11	.56- .62	.65- .71	FH11	.52- .57	.64- .70
	FH12	.63- .68	.72- .79	FH12	.58- .63	.71- .77
	FH13	.69- .75	.80- .87	FH13	.64- .70	.78- .85
	FH14	.76- .83	.88- .96	FH14	.71- .77	.86- .94
	FH15	.84- .91	.97- 1.06	FH15	.78- .85	.95- 1.03
	FH16	.92- 1.00	1.07- 1.16	FH16	.86- .93	1.04- 1.13
	FH17	1.01- 1.11	1.17- 1.28	FH17	.94- 1.03	1.14- 1.25
	FH18	1.12- 1.22	1.29- 1.41	FH18	1.04- 1.13	1.26- 1.38
	FH19	1.23- 1.34	1.42- 1.55	FH19	1.14- 1.25	1.39- 1.52
	FH20	1.35- 1.47	1.56- 1.71	FH20	1.26- 1.37	1.53- 1.67
	FH21	1.48- 1.62	1.72- 1.87	FH21	1.38- 1.51	1.68- 1.83
	FH22	1.63- 1.78	1.88- 2.06	FH22	1.52- 1.65	1.84- 2.01
	FH23	1.79- 1.95	2.07- 2.26	FH23	1.66- 1.81	2.02- 2.21
	FH24	1.96- 2.15	2.27- 2.48	FH24	1.82- 1.99	2.22- 2.43
	FH25	2.16- 2.35	2.49- 2.72	FH25	2.00- 2.19	2.44- 2.66
	FH26	2.36- 2.58	2.73- 2.99	FH26	2.20- 2.39	2.67- 2.92
	FH27	2.59- 2.83	3.00- 3.28	FH27	2.40- 2.63	2.93- 3.21
	FH28	2.84- 3.11	3.29- 3.60	FH28	2.64- 2.89	3.22- 3.53
	FH29	3.12- 3.42	3.61- 3.95	FH29	2.90- 3.17	3.54- 3.87
	FH30	3.43- 3.73	3.96- 4.31	FH30	3.18- 3.47	3.88- 4.22
	FH31	3.74- 4.07	4.32- 4.71	FH31	3.48- 3.79	4.23- 4.61
	FH32	4.08- 4.39	4.72- 5.14	FH32	3.80- 4.11	4.62- 4.9
	FH33	4.40- 4.87	5.15- 5.6	FH33	4.12- 4.55	5.0 - 5.5
	FH34	4.88- 5.3	5.7 - 6.2	FH34	4.56- 5.0	5.6 - 6.0
	FH35	5.4 - 5.9	6.3 - 6.8	FH35	5.1 - 5.5	6.1 - 6.6
	FH36	6.0 - 6.4	6.9 - 7.5	FH36	5.6 - 5.9	6.7 - 7.3
	FH37	6.5 - 7.1	7.6 - 8.2	FH37	6.0 - 6.6	7.4 - 8.0
	FH38	7.2 - 7.8	8.3 - 9.0	FH38	6.7 - 7.2	8.1 - 8.7
	FH39	7.9 - 8.5	9.1 - 9.9	FH39	7.3 - 7.9	8.8 - 9.7
	FH40	8.6 - 9.4	10.0 -10.8	FH40	8.0 - 8.7	9.8 -10.5
	FH41	9.5 -10.3	10.9 -11.9	FH41	8.8 - 9.5	10.6 -11.7
	FH42	10.4 -11.3	12.0 -13.1	FH42	9.6 -10.5	11.8 -12.7
	FH43	11.4 -12.4	13.2 -14.3	FH43	10.6 -11.5	12.8 -14.0
	FH44	12.5 -13.5	14.4 -15.7	FH44	11.6 -12.6	14.1 -15.3
	FH45	13.6 -14.9	15.8 -17.2	FH45	12.7 -13.8	15.4 -16.6
	FH46	15.0 -16.3	17.3 -18.9	FH46	13.9 -15.1	16.7 -18.3
	FH47	16.4 -18.0	19.0 -20.8	FH47	15.2 -16.7	18.4 -20.0
	FH48	18.1 -19.8	20.9 -22.9	FH48	16.8 -18.3	20.1 -21.9
	FH49	19.9 -21.7	23.0 -25.2	FH49	18.4 -20.2	22.0 -23.9
	FH50	21.8 -23.9	25.3 -27.6	FH50	20.3 -22.2	24.0 -26.2
	FH51	24.0 -26.2	27.7 -30.3	FH51	22.3 -24.3	26.3 -28.8

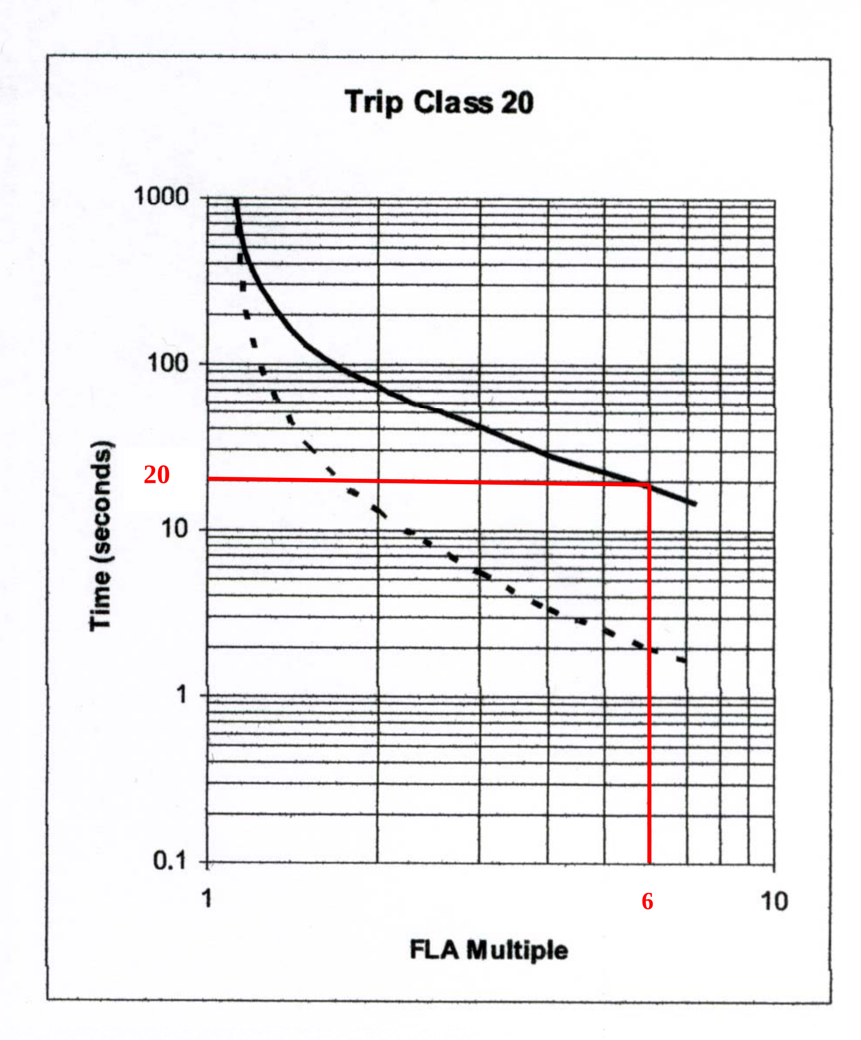
Question

What is Class 10 and Class 20 Thermal OLR curves?

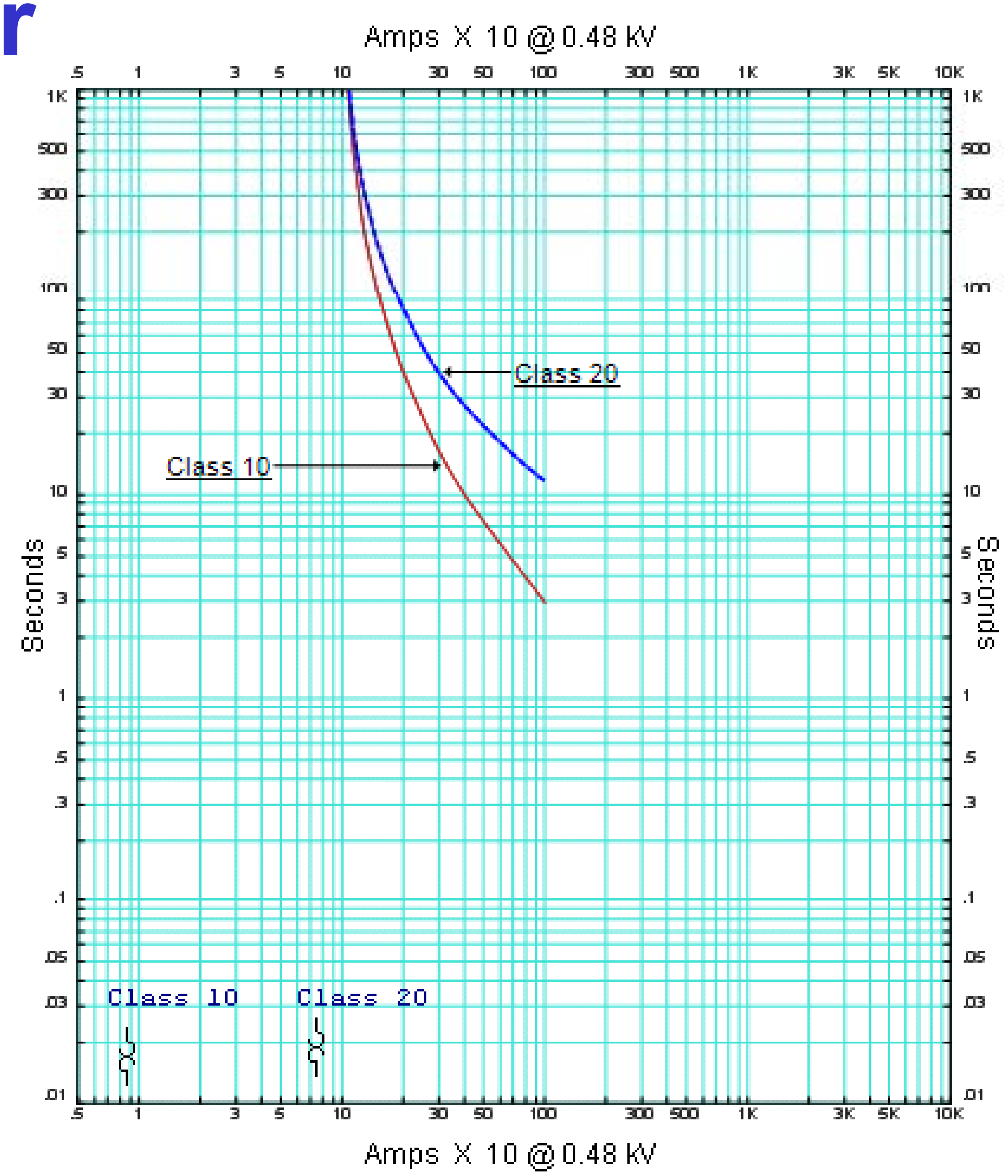


Answer

- At 600% Current Rating:
  - Class 10 for fast trip, 10 seconds or less
  - Class 20 for, 20 seconds or less (commonly used)
  - There is also Class 15, 30 for long trip time (typically provided with electronic overload relays)



Answer



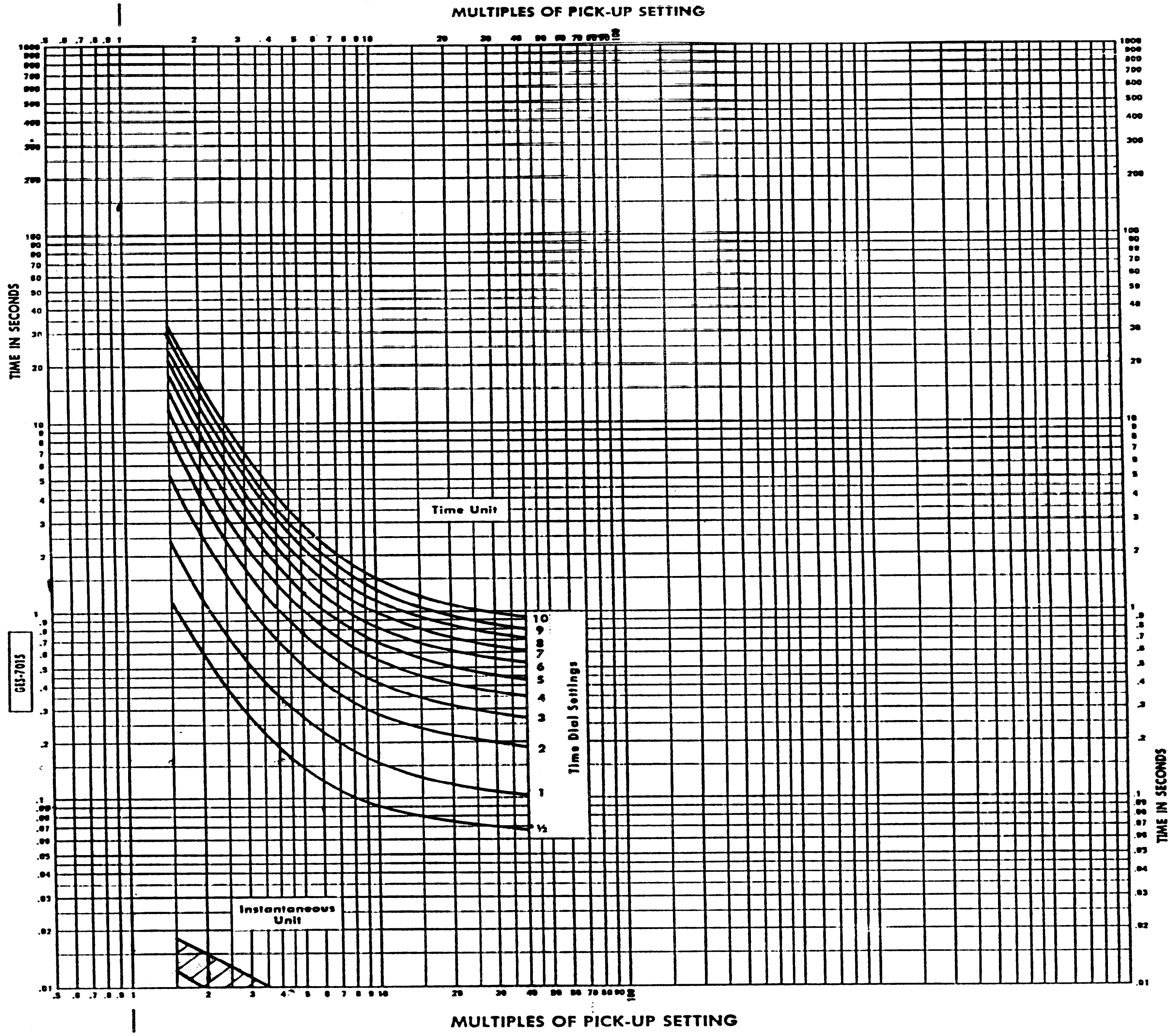
Amps X 10 @ 0.48 kV
.5
1
3
5
10
30
50
100
300
500
1K
3K
5K
10K
1K
500
300
100
50
30
10
5
3
1
.5
.3
.1
.05
.03
.01
Seconds
Class 20
Class 10
Class 10
Class 20

Overload Relay / Heater

- When the temperature at the combination motor starter is more than ±10 °C (±18 °F) different than the temperature at the motor, ambient temperature correction of the motor current is required.
- An adjustment is required because the output that a motor can safely deliver varies with temperature.
- The motor can deliver its full rated horsepower at an ambient temperature specified by the motor manufacturers, normally + 40 °C. At high temperatures (higher than + 40 °C) less than 100% of the normal rated current can be drawn from the motor without shortening the insulation life.
- At lower temperatures (less than + 40 °C) more than 100% of the normal rated current could be drawn from the motor without shortening the insulation life.

Overcurrent Relay

- Time-Delay (51 – I>)
- Short-Time Instantaneous (I>>)
- Instantaneous (50 – I>>>)
- Electromagnetic (induction Disc)
- Solid State (Multi Function / Multi Level)
- Application



GENERAL ELECTRIC

Ratings (Amperes)
Time Unit: 0.5-4, 1.0-12
Instantaneous Unit: 2-50, 6-150

Frequency Rating
60 Hertz

TIME OVERCURRENT RELAY

IFC 53 RELAY

Very Inverse Standard Time
Time-current Curvés

GES-7015

Settings Time Unit (Taps)	Inst. Unit
0.5, 0.6, 0.7, 0.8, 1.0, 1.2, 1.5, 2.0, 2.5, 3.0, 4.0	Continuously Adjustable
1.0, 1.2, 1.5, 2.0, 2.5, 3.0, 4.0, 5.0, 6.0, 7.0, 8.0, 10.0, 12.0	

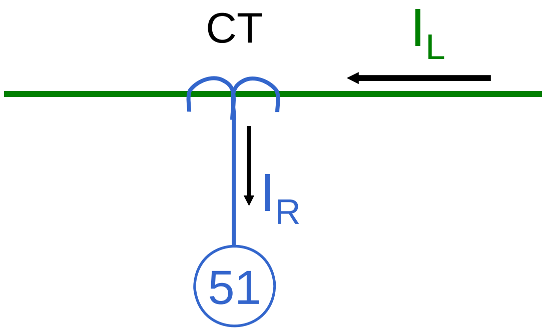
11-76 (2M)

GENERAL ELECTRIC CO., POWER SYSTEMS MANAGEMENT, PHILADELPHIA, PA. 19142

Time-Overcurrent Unit

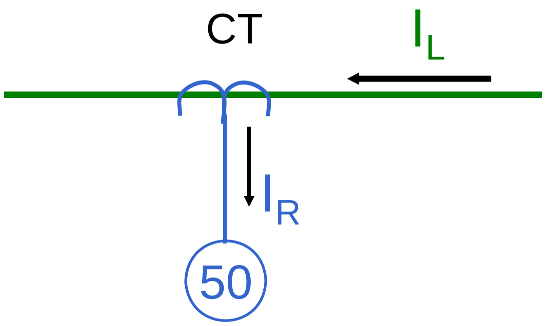
- Ampere Tap Calculation
  - Ampere Pickup (P.U.) = CT Ratio x A.T. Setting
  - Relay Current (I_R) = Actual Line Current (I_L) / CT Ratio
  - Multiples of A.T. = I_R/A.T. Setting

    = I_L/(CT Ratio x A.T. Setting)



Instantaneous Unit

- Instantaneous Calculation
  - Ampere Pickup (P.U.) = CT Ratio x IT Setting
  - Relay Current (I_R) = Actual Line Current (I_L) / CT Ratio
  - Multiples of IT = I_R/IT Setting

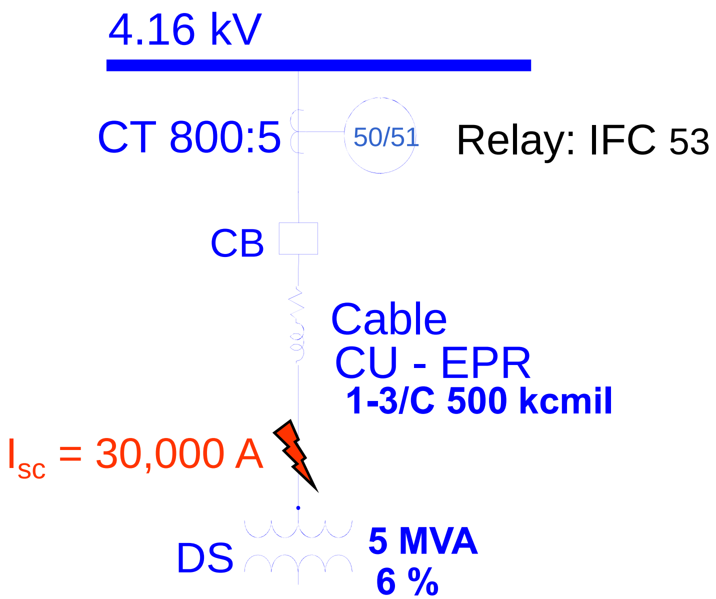


= I_L/(CT Ratio x IT Setting)

Relay Coordination

- Time margins should be maintained between T/C curves
- Adjustment should be made for CB opening time
- Shorter time intervals may be used for solid state relays
- Upstream relay should have the same inverse T/C characteristic as the downstream relay (CO-8 to CO-8) or be less inverse (CO-8 upstream to CO-6 downstream)
- Extremely inverse relays coordinates very well with CLFs

Situation



4.16 kV

CT 800:5

50/51

Relay: IFC 53

CB

Cable
CU - EPR
1-3/C 500 kcmil

I_{sc} = 30,000 A

DS

5 MVA
6 %

Calculate Relay Setting (Tap, Inst. Tap & Time Dial)
For This System

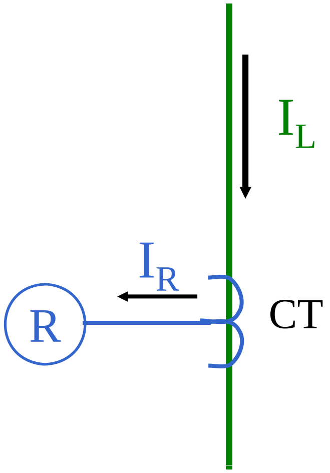
Solution

Transformer:

$$\mathrm{I}_L = \frac{5{,}000kVA}{\sqrt{3}\times 4.16kV} = 694A$$

$$\mathrm{I}_\mathrm{R} = \mathrm{I}_\mathrm{L} \times \frac{5}{800} = 4.338A$$

$$\mathrm{I}_{Inrsuh} = 12\times 694 = 8{,}328A$$



Set Relay:

$$125\%\times 4.338 = 5.4A$$

$$TAP = 6.0A \qquad (6/4.338 = 1.38)$$

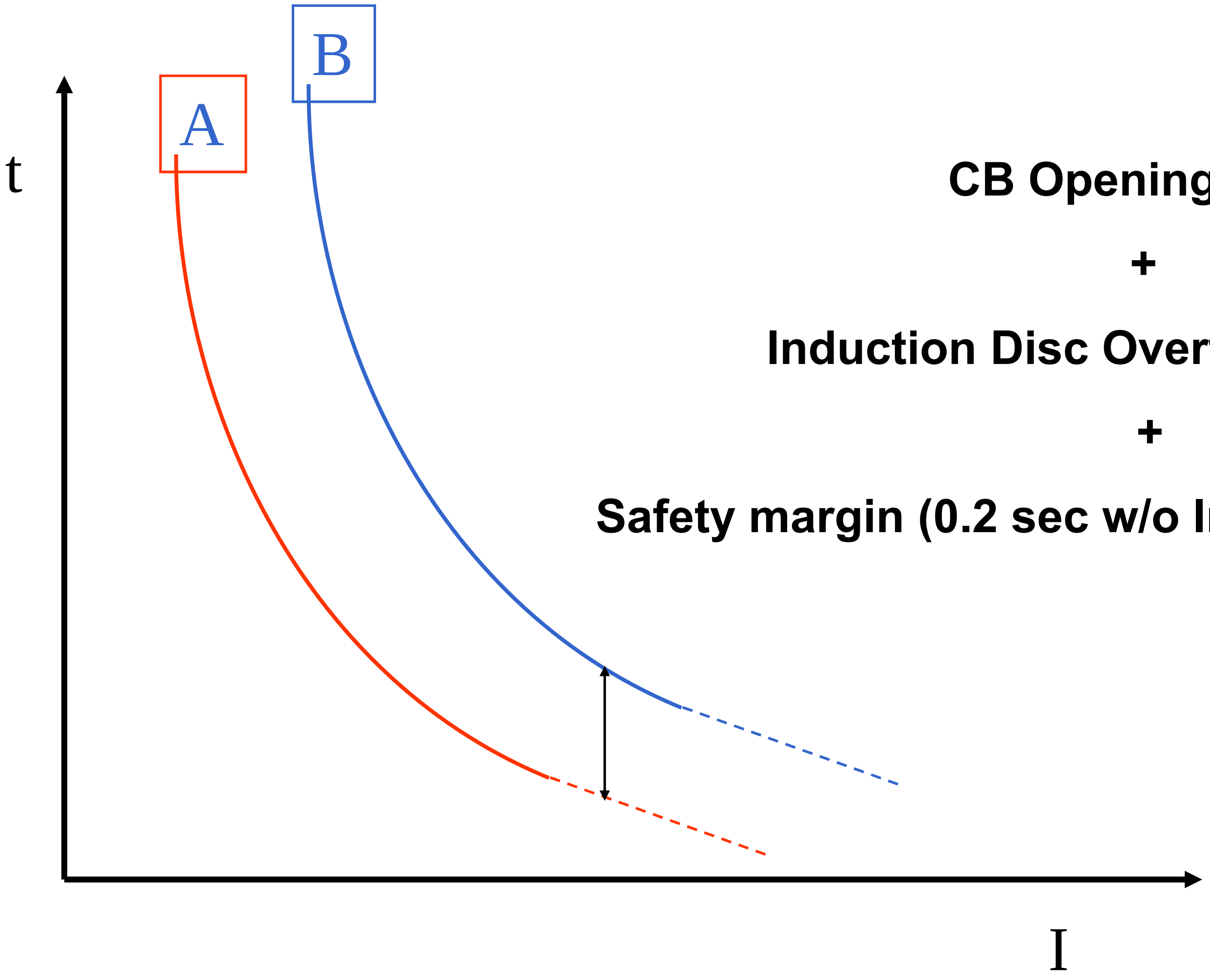
$$TD = 1$$

$$Inst(50) = 8{,}328\times\frac{5}{800} = 52.1A => 55\ \mathrm{A}$$

Question

What T/C Coordination interval should be maintained between relays?

Answer



CB Opening Time

+

Induction Disc Overtravel (0.1 sec)

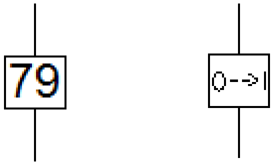
+

Safety margin (0.2 sec w/o Inst. & 0.1 sec w/ Inst.)

Recloser

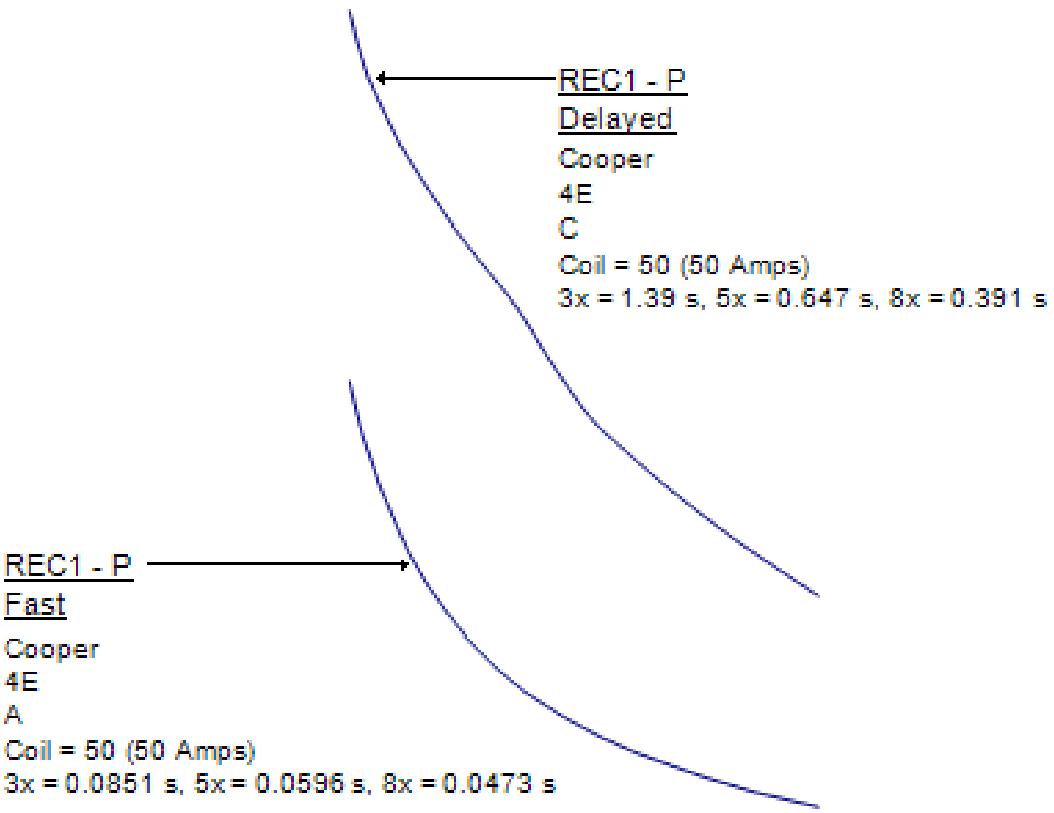
- Recloser protects electrical transmission systems from temporary voltage surges and other unfavorable conditions.
- Reclosers can automatically "reclose" the circuit and restore normal power transmission once the problem is cleared.
- Reclosers are usually designed with failsafe mechanisms that prevent them from reclosing if the same fault occurs several times in succession over a short period. This insures that repetitive line faults don't cause power to switch on and off repeatedly, since this could cause damage or accelerated wear to electrical equipment.
- It also insures that temporary faults such as lightning strikes or transmission switching don't cause lengthy interruptions in service.

Recloser Types



- Hydraulic
- Electronic
  - Static Controller
  - Microprocessor Controller

Recloser Curves



REC1 - P
Delayed
Cooper
4E
C
Coil = 50 (50 Amps)
3x = 1.39 s, 5x = 0.647 s, 8x = 0.391 s

REC1 - P
Fast
Cooper
4E
A
Coil = 50 (50 Amps)
3x = 0.0851 s, 5x = 0.0596 s, 8x = 0.0473 s